APPLYING EXPERT SYSTEMS IN THE COMMERCIAL ENVIRONMENT

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INTRODUCTION

The premise behind this paper is that Artificial Intelligence in general and Expert Systems in particular can (and do) play an important role in commercial computing. AI is out of the laboratory and the companies who are using it in their mainstream computing are measuring significant benefit. Expert Systems have served to improve the quality of decisions, distribute expertise throughout a corporation, consolidate the knowledge of several specialists and provide intelligent on-line training systems.

In this paper, I will take a pragmatic approach to AI. I will define what Expert Systems are and give some concrete and interesting examples of how they are being used effectively. From there I will look at how you can introduce this technology into your environment - what resources are available to you and how to recognize whether or not your application lends itself to Expert System technology.

Artifical Intelligence has reached a new maturity and we are seeing AI companies form consortia. AI is no longer at the crossroads stage; firms are now using it as a part of the way they do business. In fact, the future of AI in the commercial world is in embedded or "hybrid" applications which combine different generations of software technology to take advantage of the strengths of each.

ARTIFICIAL INTELLIGENCE

AI is a broad-based technology that encompasses work in fields such as natural language processing, vision systems and speech recognition and synthesis. The goal of AI scientists has always been to develop computer programs that in some way "think". It is a big field with a lot of research underway but most of AI's commercial impact so far has been due to Expert Systems - programs that represent in software form the knowledge of human experts.

Until recently the role of computers has been mainly to perform tasks at which human beings are not particularly adept, such as filing and sorting information. But people are good at tasks involving language, concepts and abstract ideas and that is what AI is all about. Artificial Intelligence represents a fundamental change in computing but it is not meant to replace the tools and techniques we currently have in use. AI simply gives us more power to solve the problems people encounter.

EXPERT SYSTEMS

Expert Systems are computer programs that model the reasoning of a specialist in a narrow domain of expertise. At this point I will take a moment to explain the difference between Expert Systems and Knowledge-Based Systems - terms often used interchangeably. By definition, an Expert System is just that - a system that performs better than or at least as well as a human expert. A Knowledge-Based System is a more general purpose term which simply implies that the source of the program's power is a large body of task-specific knowledge. Most of the systems in the field today are truly Knowledge-Based only; that is, they have not and may never achieve an expert level. These systems perform as assistants, colleagues and teachers to novices. As you can see, it is less technically precise to use the term "Expert System" in most cases. In this paper, however, I have decided to use Expert System (the more recognized term) to mean both Expert and Knowledge-Based Systems.

"Expert" Systems do not contain a precise step-by-step formula or algorithm for solving a well-defined problem. Instead, they use a collection of if-then rules, ranging in number from ten to several thousand, that tell a user sitting in front of a terminal what to do at each particular stage of a job. American Express, for example, has developed an Expert System to advise its credit authorizers and a rule in that system may be: "If a credit card has been reported lost and the cardholder has since recovered it and can prove his identity, then approve the charge."

Expert Systems are good at solving complex problems that have no "right" answer or problems with many interacting bits of information that vary from case to case, such as the best mix of components for a big computer system.

One of the industries that has embraced Expert Systems is Financial Services. Companies in this industry tend to deal with a high volume of important transactions that involve judgment and some of these companies would even characterize themselves as "decision making factories". Expert Systems can provide a means to automate that process.

A key strength of Expert Systems is their ability to have self knowledge. A program "knows that it is doing" if it can explain its decisions on demand. This capability is usually referred to as an Explanation Facility. In a rule-based Expert System, the user can ask "Why" the system made a particular decision or recommendation and the system will give a sequential display of which rules acted on which facts to arrive at a certain conclusion.

Expert Systems are characterized by their separation of the Inference Mechanism from the Knowledge Base. Because of that separation, we can provide an explanation facility that simply traces the rules that contributed to a conclusion or decision. Moreover, an Expert System's "knowledge," made up of rules and facts, can be treated like data. We can add to it, change it, and examine it, all without changing the program that uses it. Expert Systems give us far more flexibility in dealing with symbolic data than do traditional technologies. In addition, the rules can be heuristic in nature which allows us to deal more effectively with problems having a large search space.

EXPERT SYSTEM DEVELOPMENT TOOLS

Expert Systems may be developed using conventional languages, one of the AI languages (Lisp or Prolog) or Expert System Shells.

Conventional languages tend to be a poor choice for developing Knowledge-Based applications. Conventional languages do not provide any reasonable form of flexible control structures for rule selection, evaluation and execution. Conventional languages cannot evaluate themselves and cannot treat their rules as data.

As for the AI languages available, Lisp programs, based on lists and emphasizing increased programmer control, are favoured in the US, while Prolog products, which rely on database-like queries and emphasize speed, are employed extensively in Europe and Japan. Specialized computers are often needed to execute Lisp quickly, but these are not needed for Prolog. According to Artificial Intelligence Markets, Prolog will continue to grow in importance. Lisp will evolve into a system manager language; systems management functions will be in Lisp, and they will be layered between the operating system and the applications. Prolog and other languages (including conventional languages) will serve as secondary, application languages which will be called from Lisp.

Expert System Shells look after the complex programming tasks, simplifying the building of an Expert System, thus leaving the builder free to concentrate on the knowledge acquisition

process. General purpose shells may prove somewhat restrictive, although they are becoming increasingly more functional all the time.

Some Packaged Expert System Shells are:
- Knowledge Craft (Carnegie Group)
- ART (Inference)
- KEE (IntelliCorp)
- ESE (IBM)
- TWAICE (Logicware/Brant)
- S.1 (Teknowledge)

Many of the AI languages and tools are available on conventional rather than specialized hardware. From the perspective of the more sophisticated PC-based Expert Systems tool vendors and the larger conventional hardware and software vendors, the AI market is just beginning to open up. A report published by Ovum Ltd. concluded that the Expert System industry is now established and forecasts that the market will grow to $1.9 billion by 1992.

EXPERT SYSTEM APPLICATIONS

Some companies, like American Express, are making big investments of time and money in large, top-of-the-line systems. Others, like GM and Ford, are treating Expert Systems as a strategic technology and buying a stake in big vendors of the software.

Du Pont takes another approach, letting the user of the Expert System build it himself with existing hardware and inexpensive development software. Du Pont will save $10 million this year - a 1,500% return on software and labour costs. They have 500 systems in various stages of development, with 100 in routine commercial use.

Digital Equipment Corporation has been involved in AI for a long time and has applied 40 big Expert Systems to nearly every facet of its operation. DEC says its Expert Systems save it more than $25 million a year.

The first commercial Expert System was XCON - DEC's Expert Configurator. It was begun in 1978, fielded in 1981 and is used to configure all DEC computers. It configured about 50,000 orders in 1986. DEC estimates that 99% of the systems XCON specifies are properly configured and this saves the company about $6-8 million each year. DEC's former configuration experts have become XCON's supervisors and they check its configurations.

During its first year of operation, XCON had months when 40% of its orders were rejected by its supervisors. When XCON was

fielded, it was a very inexperienced expert; it had only configured a tiny fraction of the orders that it faced during a typical month in the field. Its progress from "new expert" to "seasoned expert" took about a year.

DEC also has Expert Systems to assign fulfilment sites (factories) to line items in the orders, match all new configuration requests to modules or computers that were assembled for cancelled orders, paperwork management, floor loading, inventory management, a work-in-process dispatcher, a system to co-ordinate and drive two robots that deliver the work-in-process items, a system to analyze tape drive failures and more.

American Express invited Inference to build an Expert System to help ordinary authorizers perform as well as experts. AMEX has standard statistical models that essentially look for charges that fall outside the typical credit patterns established for different types of cardholders. Following simple guidelines, these programs approve most transactions automatically. But when the models find an aberration, they will not automatically disallow the transaction. Instead, a "maybe" recommendation is transmitted to a human authorizer located at one of four sites around the USA who must search through sixteen screens of information to make a decision.

Inference helped AMEX turn the authorizers' "rules" into a software program called Authorizer's Assistant. Authorizer's Assistant summarizes pertinent information on a single screen and makes a recommendation. It has cut the time of a transaction by 20% to 30% and has helped the average authorizer reduce bad judgments by about 75%.

The system allows American Express to keep pace with its growing number of transactions without hiring a large number of new authorizers. The system's success has relied on the fact that the Expert System can communicate with the data base. It is not an isolated system. Another key component is that the area is well understood with a comprehensive training manual available.

Ford Motor Company has more than 3000 robots installed today with expectation of 5000 to 7000 by 1990. Their maintenance engineers specializing in robot repair were being overwhelmed so Ford turned to its Robotics Centre to build a prototype diagnostic and repair Expert System. The prototype was completed in six weeks by two people with no previous AI experience. The system contains about 100 rules and takes maintenance personnel step by step through the procedure of diagnosing and fixing robot problems. According to Morgan Whitney, the Centre's director, the rule base probably covers only about 20% of the rules that will ultimately have to be written but this has proven to be sufficient for 60-80% of the

problems people encounter.

GM, which owns 11% of Teknowledge, has an installation that enables electric motor designers with six months' experience to emulate the skills of 20-year veterans. This cuts the time for a typical job from two or three days of work spread over a few weeks to half an hour.

McDonnell Douglas Helicopter Co. has a project underway to design software to help maintain four Apache subsystems: avionics, flight controls, fuel and the auxiliary power unit. The intelligent fault locator used historical maintenance data to enable technicians to isolate maintenance problems. The crew chief enters the nature of the problem into the computer, which then takes him through a series of steps that quickly identify the problem. The system takes the guesswork out of maintaining the four subsystems. It reviews the historical data and predicts the cause of the problem and the individual component responsible. In addition, a graphic display highlights the failed component.

Boeing's first system to go into daily use was Case, for Connector Assembly Specification Expert. Case tells skilled workers how to assemble each of the roughly 5,000 multiple electrical connectors on a typical airplane. Before Case, workers used to hunt through 20,000 pages of cross-referenced specifications. Case has reduced the time its engineers require to locate the specifications from 42 minutes to 5. Boeing has another project for the Navy that helps a crewman select the right types of acoustic buoys to throw into the water to locate an enemy submarine. Boeing also has a number of prototypes currently under development.

Campbell Soup Co. has developed Cooker, an Expert System that is also known as "Aldo on a Disk". Aldo Cimino retired in May as Campbell's resident expert on the hydrostatic and rotary cookers that kill bacteria. He was a storehouse of knowledge who was about to leave the plant. Instead of that, he spent about 30 days with some Knowledge Engineers from Texas Instruments over the course of eight months and now, when employees from Campbell's have a problem with their cookers, they type the symptoms into a computer, answer a series of questions and are led to the same diagnosis that Aldo would have made.

SUMMARY OF APPLICATIONS

To summarize these applications:

- XCON is the expert configurator. It contains a huge volume of expertise - more than any one human expert - and DEC benefits from consistent configurations that

always have the most up to date information.

- The American Express authorizing advisor does not really save the human authorizers much time. It does, however, ensure consistency and allows people with less experience to quickly become seasoned experts.

- Ford, GM and McDonnell Douglas all have systems that perform diagnostics. They help the user of the system quickly locate the root of the problem so that user can do what he is supposed to do - fix it.

- Boeing's Case system is similar in that it reduces the time that the human user must spend in locating the engineering specifications and it has removed the problem of keeping manuals up-to-date.

- Boeing's Helicopter Display system handles the explosion of data. It supports the pilot's decision making process by displaying all the information he requires but only that information relevant to the problem at hand.

- Cooker, by Campbell's, retained human expertise as a corporate asset. A number of companies are looking at using Expert Systems for the same purpose.

GETTING STARTED

The above examples outline how Expert System technology can be successfully applied in a number of diverse application areas. It is an interesting and exciting technology and it broadens the types of problems that we can solve in our computing environments. But how do you get started?

Probably the most important way to begin is to read some of the better known reference books on the subject. I have listed several in an appendix to this paper. From the readings, you can establish a basic understanding of the technology. Armed with an understanding of how it can be applied, you should begin developing a simple, yet representative application. You can do this by hiring a consulting firm with experience in AI to either build an application for you or work with you in the development of that application. As an alternative, you may want to undertake the whole process yourself by acquiring and learning how to use one of the AI languages or Expert System shells.

It is often best to begin on the PC and you should probably look to the PC for delivery. Your initial task should be to prove the viability of AI in your organization. If you are going to be its champion, you have to ensure that your application has a good chance of success, produces measurable

results and can be distributed to your coworkers (perhaps as a demo) so that they can see how AI can be applied in your environment. In a minute we will look at some guidelines that can help you determine if an application is a good candidate for solution by an Expert System.

We often recommend that companies in the early stages undertake to develop a prototype Expert System with the help of a consulting firm. Your staff can benefit from working with experts in the field and they gain experience by actually participating in the development of a "mini" Expert System. We feel that this is an excellent, low cost start-up solution. The education process will not take as long for your development people as it is "hands on" and you are left with a working prototype that, in addition, you can use as a model for further AI work.

Expert System shells, on the other hand, greatly simplify the process of building Expert Systems. However, your people will have to educate themselves about tools and techniques - often a rather costly process, as a whole new learning curve is generally involved. You should evaluate both alternatives based on the people you can dedicate to the task and the time available.

QUALIFYING THE CANDIDATE

Before embarking on an application, you must ensure that the project will likely make a good Expert System. Keep in mind that AI technology is just another tool available to us. Our philosophy at Brant is "don't consider AI to be a solution looking for a problem". Rather it is an alternative way to solve a problem that is not effectively solved using traditional programming tools. Research has told us that only about 20% of the problems we encounter in life are numeric or quantitative. The remaining 80% are symbolic or qualitative. AI does not replace traditional techniques but does add power to them and provides a second dimension and alternative to problem solving.

Following is a list of features that characterize an Expert System and help to qualify whether or not a candidate application may lend itself to Expert System technology. These features are:

- The domain is characterized by the use of expert knowledge, judgment and experience.

- There are recognized experts that solve the problem today.

- Expertise is not or will not be available on a reliable or continuing basis (ie: there is a need to capture the expertise because it is scarce, expensive, dependent on overworked experts or will be less available in the future).

- The task requires the use of heuristics (rules of thumb, strategies, etc). It may require consideration of an extremely large number of possibilities or it may require decisions to be based upon incomplete or uncertain information.

- There is an expert available to work with the project.

- The expert is capable of communicating his knowledge, judgment and experience, and the methods used to apply them to the particular task.

- The task is neither too easy (taking less than a few minutes) nor too difficult (requiring more than a few hours) for the expert.

- The system can be phased into use gracefully: some percentage of incomplete coverage can be tolerated (at least initially), and the determination of whether a sub-problem is covered by the present system is not difficult.

- The task is decomposable, allowing relatively rapid prototyping for a closed, small subset of the complete task; and then slow expansion to the complete task.

- The skill required by the task is taught to novices; thus the task is not unteachable.

- Test cases are available.

Before introducing Expert System technology into your organization, you should go through a checklist of points such as these to ensure that the project has a good chance of succeeding. You should not try to build an Expert System to solve problems which people are unable to solve. Nor should you try to solve problems that are being effectively solved using traditional techniques.

The biggest benefits will be felt if the application lies within a company's core business area where functions are performed by many people with different levels of expertise, where there is a scarcity of experts and you want to attain a higher level of expertise through an application or a training tool.

CONCLUSIONS

Expert Systems, as we have seen, have been applied successfully to commercial applications with substantial payoffs and benefits.

Barbara Sanders, director of AI systems and planning at General Motors suggests starting with small steps. "The larger-scale applications with the big payoff will come from people who developed their confidence by building smaller systems," she says.

The tools and the expertise exist today to help you begin applying Expert Systems in your commercial or technical environment. If you start small and if you follow some simple guidelines you can successfully implement Knowledge-Based systems. That will increase your understanding of how Artificial Intelligence can impact your business and give you the experience to work toward larger projects.

I urge you to consider using this technology. Expert Systems can simplify some of the more difficult problems we are attempting to solve using traditional software technology. If you have an application that applies human expertise to solve problems, consider implementing it as an Expert System. You can start small, solving a subset of the problems, and add more knowledge over time.

APPENDIX

SUGGESTED READINGS

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