SMALL TAILORED EXPERT SYSTEMS FOR PRIVATE COMPANIES

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INTRODUCTION

Interest is growing in the application of Knowledge Based Expert Systems (KBES) to assist in solving problems in the construction discipline. A number of major research and / or development projects are under way in various US institutions, however, as of the summer of 1985, the number was small considering the potential of this new technology.[1]. A few of the larger design and construction companies in the United States have also initiated KBES development projects, or are working with the research institutions but, by and large, the US construction industry is unaware of expert systems technology or fails to see it's practical and economic application to their business.

The research and development projects currently under way are typically expensive and of long duration, which may be one reason for the lack of industry interest. This approach of spending large amounts of money and time to develop complex programs may not be the best for implementation of KBES in the construction industry.

Another and probably greater reason for the lack of interest has been the need for highly trained "expert system experts" or knowledge engineers to develop the programs. Recent breakthroughs in microcomputer speed and capacity, together with the emergence of the Expert System Shell Program (ESSP) are enabling a few enlightened companies to recognize the potential of developing small, inexpensive applications for internal use in solving small but critical problems. In this approach, current company employees, the domain experts, are provided the tools to develop their own applications. The result is introduction of the technology into the company with little expense and at a pay back of up to 700%, according to one source.

This paper will discuss the internal development of small, tailored expert systems for practical industry applications, based upon case studies outside the construction industry. It will then consider adaptation of this approach to construction. A plan will be suggested for implementing small tailored systems into the construction industry, identifying advantages in this approach.

EMERGENCE OF THE EXPERT SYSTEMS SHELL PROGRAM

A brief summary of the emergence of KBES would identify the decade of the 1950's as defining the concept of Artificial Intelligence (AI) (of which KBES is a subset), the '60's as basic research into languages and primitive applications, the '70's as initial development of limited commercial applications and the '80's as moving the technology into industry. Parallel to advances in the understanding of AI, computer technology has also advanced to the point where any business, no matter how small can own their own powerful computing system, and in larger companies, each manager or engineer has his or her own system at their own work station.

Since the computer became commercially available in the early 1950's, computer application has focused on numerical analysis and data management. Help for managers and engineers to analyze problems and make decisions has been limited to these two functions. What separates the successful manager or engineer from the less successful one is the ability to make wise decisions based upon experience combined with analytical ability and data accessibility. The computer has provided a distinct benefit because it provides greatly enhanced capabilities for numerical analysis and data management. The great advantage to the microcomputer is that it puts the numerical analysis and data management tools at the fingertips of the user who needs them. Sophisticated general application programs such as spreadsheets and data base management systems allow the manager or engineer to program the uses himself, rather than depending on a "computer expert" who has no concept of the user's area of expertise, his domain. Not only does this user have the information and analytical capabilities at his fingertips but he can adapt his programs at any time, fine tuning them to better serve his needs. For this reason, the microcomputer has attained commercial success far beyond the projections of even the most optimistic of early microcomputer enthusiasts.

With the current broad availability of sophisticated microcomputer data management and numerical analysis tools the critical component which is still largely missing in the manager's tool box is assistance in reasoning, based upon experience. That the means for providing this component lie in the technology of KBES has long been recognized by experts in the field of AI, but until recently, the technology has been accessible only through specially trained experts in KBES and on large, expensive computer systems.

By 1984, microcomputer systems were gaining adequate capacity and speed to make the ESSP possible. Like spreadsheets, these general application programs were developed as shells into which particular solutions to specific problems could be programmed. They provided similar opportunity for the manager in the reasoning area as the spreadsheet and data base management software did for numerical analysis and data management. The

early programs were small, with limited capabilities, but they definitely allowed real KBES applications to be programmed without the help of an expert in KBES. Though ESSP programs were available for the 16-bit generation of microcomputer, much stronger applications were developed on more powerful "expert systems work stations" in the minicomputer category. With the new generation of microcomputers employing 32-bit microprocessors such as the Intel 80386, ESSP programs with considerable power will be available on what will soon become the standard business machine for the manager. Hence the hardware and software tools are available for the user, or domain expert, to develop his own applications.

Harmon and King[2], who classify companies in three categories: cutting-edge, advanced and normal, predicted "we expect that small systems will be developed by most advanced companies during the coming years [1985 and after], and that by 1990, these systems will be in daily use by normal companies." "Small systems ... refer to expert systems with from 100 to 500 rules. Such systems can be run on personal computers and might be called intelligent decision aids."

To date, very few companies have taken advantage of the new generation of KBES shell software. This is due to a large extent because of lack of awareness. Even for those who might be aware of KBES technology, the concept of a machine to assist in reasoning is much harder to accept than the concept of a machine to help numerical analysis, which has been in existence since the invention of the abacus, or a machine to help manage data, which has been the major business function of the computer since it's introduction into industry. An aid in reasoning seems to be too close to our humanness since the ability to reason is accepted as that which separates us from lower forms of life.

PRACTICAL APPLICATION OF SMALL TAILORED SYSTEMS

Of those companies where some developmental work with the ESSP is going on, the usual approach is for one or at most just a few individuals to become intrigued with the possibilities of the new technology and to initiate some experimental inquiries, in many cases on their own time. Only a few companies have begun to approach the introduction of expert system development tools into corporate life on a systematic basis, in much the same way other application packages have been introduced. The experience of two of these companies will be reviewed here.

Dupont has implemented a corporate wide KBES literacy program under the leadership of AI program director Ed Mahler. "We are a catalyst group... We train end users on three development packages: 1st Class, Insight 2 Plus and TIMM"[3]. (Texas Instruments PC Easy has recently been introduced into the program as well). Mahler's group presents 2-Day courses for company employees which cover the basics of knowledge systems, knowledge acquisition and software literacy on one of the selected shell

programs. The participants enter the program already experienced in microcomputer use, thus training can focus just on KBES. When the employees return to their work stations and when they identify problems that appear appropriate for KBES solution, they develop simple programs within one of the shells for their own use.

Dupont's program began in October of 1985. About 50 participants are trained each week, with the total of trained employees now at about 800. Ed says[4] hundreds of simple applications have been programmed. Since the managers already have computers and the software is site licensed, the investment is small, limited to only training costs, and annual return on investment is on the order of 700%

Another company taking a corporate wide approach is Ingersoll Rand. Director of Technology Wally McGahn[5] has addressed introduction of KBES technology in two stages. The first was a short (2 hour) overview of KBES presented to all company managers who could possibly have an interest in the technology. The presentations took place in about 30 locations around the US during the period between September of 1986 and February of 1987 and reached about 450 people. The intent was to acquaint all managers with the potential and state of the art of KBES as a problem solving tool available for their personnel. Topics included what KBES is, what it does, types of problems appropriate for KBES tools, situations appropriate for KBES application, examples of applications in the company and in other companies and finally an overview of the training available through McGahan's department. He then asked these managers to select individuals in their divisions for extended training.

The second phase of the program was to provide KBES literacy training for the selected individuals consisting of two 2-day programs approximately one month apart. The format for day 1 of the first session was primarily lecture covering basic KBES technology. Day two took the form of a hands on workshop in use of two shell programs: Insight 2 Plus and Exsys. These are felt by Wally to be representative of two distinct approaches available in shell programs: Insight 2 Plus providing more of a free format, and Exsys with a more structured approach based upon menus. After this first 2-day session, the participants are expected to return to their work stations and try to identify ways in which they can apply the newly learned technology.

The second 2-day session concentrates on hands on practice. Questions, problems or concerns arising from the month of effort in applying the new skills are addressed. New material focusing on knowledge acquisition is covered, including a simulated interview. The objective here is to prepare the participant to go beyond development of tools for his own use and to work with colleagues in developing tools to meet their needs. This second phase of the program was presented in 7 locations and trained about 65 employees.

Ingersoll Rand's training program is now completed and results are beginning to show. About a dozen programs are currently under development and two have been completed, one consisting of about 700 rules and the other of about 1500. These are larger than those currently under development which are anticipated to be in the 150 to 200 rule range. One benefit Ingersoll Rand is beginning to see is the cross fertilization of ideas, with one person picking up a program developed by another and adapting it to meet a specific need he has. This significantly cuts down on the effort required to program a solution from scratch.

A number of other benefits have been identified at both Dupont and Ingersoll Rand. In addition to the obvious advantage of immediately applicable solutions to specific problems, an intangible benefit is that a significant number of employees are being trained in the basics of the new technology of KBES. As larger, faster computer systems with stronger KBES software become available, these employees will be in a position to take immediate advantage of them and will be prepared to lead in application of what is considered to be technology which will have tremendous impact between now and the end of the century. Moreover, as employees become personally familiar with the application of KBES, they will be looking for new and innovative ways to use the technology in their domain of expertise. This can not be achieved if professional knowledge engineers have to develop "black box solutions" for domain experts who may benefit directly from the specific program but who will not understand the technology and how it can or cannot be further applied. Many of the solutions currently coming from this newly trained group may be of small value, but a number of the applications have proven valuable and inevitably, with the large and growing base of KBES literate employees, some major breakthroughs will occur which will greatly benefit the company.

According to Cornelius Willis[5], Level 5 Research (developers of the Insight series of ESSP), other companies in diverse industries are also implementing KBES development programs. Small applications have been developed by the US Bureau of Mines which has a set of 15 knowledge bases chained together to help check mines for dust control in conformance with Occupational Safety and Health Administration standards. Peat Marwick & Mitchel, a large accounting firm has taken a different approach in developing a much larger system of about 4500 rules. This program, which will be distributed to their auditors nation wide, follows auditors into a bank to assist in checking customers files. The key point in both these development projects is that ESSP programs were employed by the domain experts, not knowledge engineers.

RELUCTANCE OF THE CONSTRUCTION INDUSTRY TO APPLY EXPERT SYSTEMS

A few progressive construction companies are working with researchers or internally to apply KBES to solve construction industry problems, but the bulk of the development work seems to be in academic or research institutions. Concern has been expressed at the Construction Engineering Research Laboratory (CERL), Champaign, Illinois, that though CERL has developed several operational programs, contractors are slow to use them. This is consistent with constructor's traditional approach toward new technology. A clear example of this reluctance to use state of the art technology is found in the area of critical path scheduling which has only gained fairly widespread acceptance in the industry, even after many years and much pressure from owners.

Industry reluctance seems to stem from the following:

* Necessity, until recently, to have KBES experts instead of domain experts develop the programs.

* Great investment of time, money and expert personnel required to develop KBES programs.

* Fear of the risk in using unknown technology.

* Psychological barriers in accepting a "machine that thinks".

* Lack of proven economic advantages in investing in this new technology.

* Reluctance to divulge company expertise.

Of all the impediments to KBES introduction into the construction industry, probably the greatest has been the need to guard proprietary information. For the contractor working with research organizations to develop large, expert systems for general distribution, the potential and in fact the probability exists for their expertise to end up in the hands of competitors to be used against them. With the advent of the ESSP, this problem is overcome if the contractor develops programs in-house.

In fact, programs like those established by Dupont and Ingersoll Rand demonstrate that many of the problems identified above have been overcome by the new KBES technological advances and innovative approaches to implementation. They have demonstrated that an immediate pay back can be achieved through a company wide commitment to establish a program to support development of small, tailored KBES applications for internal use. The long term potential of such a program has yet to be assessed, but it appears to be significant.

IMPLEMENTING SMALL TAILORED SYSTEMS IN THE CONSTRUCTION INDUSTRY

The construction industry is a tremendously fertile field for the application of KBES technology. In each of the tens of thousands of construction companies in the US, and hundreds of thousands of companies around the world, experts are in short supply in such areas as cost estimating, cost management, time management, contract coordination, supervision of field operations, and many other activities. Companies feel fortunate if they have a few experts in these areas and virtually all companies would secure more and better experts if they could. The industry is in desperate need of more and better experts.

KBES technology is not a simple and complete solution to the need for more and better experts in the construction industry, but it's potential to significantly help the situation is great. The problem, then, is how to initiate use of KBES with as little disruption as possible. The question of disruption is critical because typically, construction companies are over extended and understaffed as well as having very tight budgets. If the technology is to be implemented, it must be accomplished with as little disturbance as possible.

The answer lies in the cases just reviewed. Larger construction companies can implement training programs much like those at Dupont and Ingersoll Rand. However, the vast majority of construction companies are small and have no resources for training in critical areas, say nothing of something as exotic as KBES. The two step approach applied at Ingersoll Rand, however, could be adapted effectively for the industry. A short overview of the technology could be developed for presentation at construction industry meetings such as those of the trade organizations and professional societies with the objectives of:

* Describing what a KBES is
* Identifying what they can be used for
* Presenting case studies demonstrating cost effective applications
* Describing how the technology can be implemented
* Identifying appropriate problems and appropriate situations for their use
* Inviting participation of selected employees in more extensive training

A Phase II training program would have to be developed to provide the in depth follow up training. This could be provided at regional locations for participants from smaller companies or, for larger companies it could be provided in an internal program. This training program would have to be developed by people who

know training, the construction industry and the technology of KBES. It should include extensive training materials, professional instructors and provision for limited consultation for participants after they have attended the workshops.

Another type of training could be provided for the company of moderate size which wants to have a greater level of internal expertise and do the training themselves. This would take the form of an instructor training workshop that would have the prerequisite of completion of the Phase II training.

CONCLUSIONS

The technology of KBES shows great potential for application in the construction industry. The industry, however is reluctant to adopt the technology. The traditional approach of spending large amounts of money and time to develop complex programs may not be the best for implementation of KBES technology in the construction industry, especially with the advent of powerful, inexpensive microcomputer systems and the ESSP. In order to overcome reluctance in the industry, the approach of broadly disseminating training and encouraging the domain experts to develop small applications for their own use has many advantages.

Effective implementation programs have been initiated in other industries through internal training programs broadly delivered through out the company. This puts the power of KBES technology in the hands of the user where it belongs and overcomes many of the problems impeding acceptance by the construction industry such as development time and expense, and exposure of sensitive company proprietary information.

Since most construction companies are small, a training program is suggested that will enable KBES training for selected company employees who can then return to their companies to begin internal implementation of the technology. In this way cost is minimized, proprietary information is guarded and yet the technology is disseminated. A cadre of domain experts who are trained in basic KBES theory and application will permeate the industry and establish a foundation for introduction of KBES into the construction industry. This group of constructors will provide the leaders who will develop advanced applications of expert systems for the construction industry as the technology advances.

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