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THE IMPACT OF EXPERT SYSTEMS*

Prepared by the

Regional and Country Studies Branch

Studies and Research Division

109

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CONTENTS

INTRODUCTION

As part of UNIDO's studies and research programme, the Regional and Country Studies Branch examines trends and patterns in the industry of developed countries, in order to identify opportunities and problems these may create for developing countries. This paper is intended to give a short overview of the impact of expert systems, an important aspect of informatics that is now rapidly developing.

Expert systems, a branch of artificial intelligence, are software products which attempt to embody human expertise in a particular field and to convey it to a user seeking answers to a problem in that field. They are the subject of increasing research and development efforts by governments and private companies, mostly in industrialized countries, and are thought to have very great potential in most economic activities.

The paper begins with a brief description of what an expert system is. The second section contains a survey of existing expert systems that may show how wide are the possible application. Section 3 examines developments in this field, and Section 4 looks at the ways in which developments in computer hardware may be influencing the growth of expert systems applications.

Section 5 examines the main groups influencing the development of expert systems, including computer hardware manufacturers and software and systems companies. The role of governments in developed countries as supporters of R&D efforts in this field is also examined. Section 6 briefly looks at possible future developments, and Section 7 concludes by drawing some implications for developing country policies.

The report has been prepared by the Regional and Country Studies Branch of UNIDO.

1. Expert systems: an introduction

An expert system is a computer programme and database that behaves rather like a human expert: it answers questions about new problems based on its experience of previous problems. Expert systems is the more common name, but knowledge-based systems is a term also used.

This may appear fanciful, but in fact this definition is a reasonable summary of what expert systems do. They are not confined to the world of academic research: expert systems are produced commercially and used to make commercial decisions. They are used in medicine, manufacturing, law and many other fields. Their use is spreading, and the potential number of applications is very large.

An expert system can be divided into three parts: the "shell", the knowledge base, and the user interface. The shell is the reasoning power of the system, the process by which it applies rules drawn from experience to the problem in question. This reasoning process is theoretically of general applicability: thus shells are often sold separately, or with only a small sample database. The user interface is the way in which questions can be posed and the data added to. Sometimes the expert system will also explain the process by which it arrived at a conclusion. This means it will indicate the sequence of rules which it has applied in order to answer the question posed. Such a feature can be particularly important not only in constructing the system but in showing the user that a systematic and reliable chain of reasoning is applied.

In practice, however, the type of the reasoning and sophistication required will vary from one problem area to another. The problem may be one of identification (what is the chemical compound?) or of decision-making (what is the cheapest way to fly Vienna-New York-Caracas-Vienna?) It should be noted that both problems require a search of database, but the second requires a further search of possible solutions in response to the supplied criterion of cheapness.

One can envisage the system, in the first example, asking questions that chemists have found useful in narrowing down the area of search for the identity of the unknown compound (e.g. what is its melting point? Is it water soluble? What is its specific gravity?) The contribution of the human experts has thus been not only in providing the general answers but also the general questions.

The second example illustrates the same point more subtly. The complex regulations on airline fares could be expressed as a series of rules, which would then form the data base to be analysed by the system. The expert system may be directed to search not just for routes that involve one change of plane between Vienna and New York, but also two or more changes. These may or may not include searches in the opposite direction, e.g. Vienna-Istanbul- Rome-New York, depending on exchange rates and local restrictions on particular types of ticket. Too detailed a search may, even with a fast computer, take too long. Thus (preferably variable) criteria of search and of reasonableness of the solution have to be incorporated in a way which would be unnecessary in the first example.

Further difficulties arise when probability enters. Some kinds of knowledge can be embodied quite well in the form of rules. If the problem is of identification, and if scientific knowledge is advanced enough, then the rule can be put in a form such as, "If A and B and C and D are all true then the answer is Z". However it may be that scientific knowledge is not advanced enough to do more than assign probabilities, e.g. "If A and B are true then the answer is Z with 70 per cent certainty". Such systems arise especially in important areas such as medicine, where diagnosis may depend on the application of a number of different rules all involving probabilities. The choice of which medical tests to apply to the patient and in which order to apply them can be vital when time is short.

It should be stressed that the above examples are intended only to be illustrative and to introduce the subject of expert systems in a non-rigorous manner. Their actual construction in terms of providing answers to real world problems is a difficult task. Nevertheless, it is one which is now being taken up with enthusiasm in many developed countries.

Experts systems are a branch of artificial intelligence (AI). The origins of AI as a science antedate the invention of computers and can be traced back at least to the work of A.N. Turing and others.[1/] The idea of machine intelligence is one that has found practical application in many other fields, such as pattern recognition, speech input and output, machine translation and the like.

2. Operational expert systems

Whatever about the attractiveness of the concept, the main interest in expert systems has to be directed towards the practicability of their construction and use. Therefore, the example of existing implementations is one that has to be closely studied. The best known of the earlier applications have been in medicine. The MYCIN system developed in California has been used extensively for the diagnosis of bacterial illnesses. A later system, INTERNIST-1 has been shown to be as successful in diagnosis the average clinician.[2/] Medicine continues as an important areas of research. Organic chemistry has seen a successful system for the identification of compounds from spectographic data, and, even more interestingly a scheme to suggest new synthesis paths for organic compounds. It has already suggested routes that are commercially viable and which had not previously been invented.

Natural resources have provided a further regarding field for expert systems, perhaps because the problems are usually very clearly defined. The prospector whether in mining or off-shore drilling, wants to know, "Should I drill here?" The point of an expert system is that it can embody all recorded previous experience as to the likelihood of a successful find, given the particular conditions and the preliminary indications deriving from sample surveys of the area. Again in the mining field, a well-known expert system called PROSPECTOR helped in finding a promising extension to an existing molybdenum deposit in the United States.[3/]

Again in the mining field, an expert system called MUDMAN is being marketed that embodies the accumulated expertise in so-called "mud engineering", the skills needed to apply drilling mud (a lubricant). The system is supplied by the mud company as a source of support to users of the product which can substitute for the limited number of experienced engineers in this field.[4/]

Other applications, catering for more complicated questions, in, however, more restricted subject areas, include insurance, investment appraisal, inventory control, training, computer operations, process and production control, fault diagnosis, etc.[5] The assembly of computers, the selection of them and the processing of housing applications by local authorities are some other examples.[6] The choice of the best components for combinations to meet customer requirements is an application for which a valve manufacturer is now using an expert system.[7]

Operational expert systems in the manufacturing sector cover the problems of process planning, production scheduling, machine problem diagnosis, as well as the areas mentioned above of order specification, completion and configuration.[8] In this last area the best-known example is Digital Equipment Corporation's internal system called XCON. This has allowed the company's sales force rapidly to select the combinational of equipment needed to meet the requirements of a particular customer, and it is estimated that it now saves the company more than £15 million a year.[9]

The provision of advice on complex but well-defined subjects is an area where early growth is obviously possible, since expert systems of this kind are the easiest to establish. One example of such an implementation is a superannuation (pension) adviser. A government department in the United Kingdom has implemented a system, using the ICL Adviser software, which guides staff through the often complex regulations. The purpose is to allow those who have enquiries about their entitlements and the options available to them to make enquiries directly of the computer.[10]

Law is another application of the advisory type of expert system. Again the domain (the area of knowledge) can be both limited and well-defined. Employment legislation in the United Kingdom is summarized in an expert system now being marketed. The system uses a total of around 1,100 rules to assist managers in understanding the basic structure of the law in this area. It allows the manager to assess whether the employee will have a claim for unfair dismissal, and it estimates the likely costs if a claim were to be successful. The same company, Expertech, also markets an expert system to clarify the regulations on sick pay, in order to determine employee entitlements in accordance with government regulations.[11]

A rather different type of expert system is one which can be described as a real-time expert system. Here the purpose is to support an experienced professional in his decision-making where this decision-making is being complicated by the speed and variety of the information he or she is receiving. An expert system can monitor the information being received and decide on the basis of pre-defined rules, whether it is changing significantly. One obvious application under significant research and development focus at the moment is in defence systems, where decisions have to be taken in the face of streams of information from all sides. However, civil applications of this kind are also developing rapidly. Decision-making with respect to certain industrial processes can be crucially dependent on timing to avoid loss or damage, as noted above, and when the flow of information is faster than the human expert can cope with, then expert systems of this type have a role to play. But the areas of banking, especially in foreign exchange dealing is another field where artificial intelligence applications are growing. The ability of systems to analyse and interpret changing trends and the relationships between them, and to apply and to change the decision-making criteria used by the human expert are of increasing importance in a financial world now operating globally for 24 hours each day.[12]

Computer manufacturers, as might be expected, have applied expert systems techniques in their own work, especially for fault-finding and diagnostics. Companies reporting such activity include Texas Instruments, Digital Equipment Corporation, Siemens, Nixdorf, Fujitsu and Tandem.[13]

3. Software trends

Research in the academic sphere has now been underway since the end of the second world war, with a major development in 1954 with the invention of LISP, a computer programming language by John McCarthy of the Massachussetts Insitute of Technology. LISP is a list-processing language, at least that is the characteristic from which its name derives. It has several other characteristics however, which also make it particularly suitable for artificial intelligence applications. Lists are collective of elements linked together in a structured way. LISP allows lists to have branches, and these to have sub- branches and so on, and the end of a list can refer back to another part, to to the beginning of the list. Now it turns out that this way of storing data can be very efficient (if a bit confusing initially) for storing knowledge (rather than data in the traditional sense). Knowledge can be thought of as a structure of facts: it is facts in a certain order and with certain relationships between them. LISP allows data to be stored in this way. Moreover, as a language, it allows these sorts of lists to be easily examined and changed. It has therefore become the major language for AI and expert systems work in the United States.

Among its drawbacks are that it is not particularly concise nor particularly comprehensible. (Its syntax for instance involves an extraordinary number of parentheses). Other languages have arisen, of which the most successful has been Prolog. This was devised in France by Alain Colmerauer in 1975.[14] It is in a sense more problem-oriented than LISP, and is particularly good at manipulating logical statements and relationships. It has become the major language in Europe for AI applications, especially in the United Kingdom, France and Hungary. What may encourage its widespread use is the launch by the Borland International Company of a Prolog compiler for the IBM Personal Computer at a cost of US $100, which means a significant increase in its accessibility. Other languages have also been developed for use in AI applications. They include smalltalk-80 and OPS5. Expert systems can be written in the traditional programming languages, such as BASIC or FORTRAN, or in newer ones such as C, even if this is not as easy to do.

However, it is likely that the main way in which the use of expert systems will spread not through the sale of LISP or PROLOG compilers or interpreters but through the availability of "shells", i.e. already written software packages which contain the reasoning processes and need only a knowledge base in a suitable form, in order to be applicable to any subject area. The creation of the knowledge base, however, seems to be the most difficult part of the construction of expert systems.

4. The influence of hardware trends

The frequently remarked fall in the price and size of microelectronics components, together with a continued increase in performance, has meant that computer power of some kind is within general reach. But it has also meant that greatly expanded computing power is available to those who previously had very limited facilities. Thus there has been a qualitative change also in the uses to which computers are being put, and there is a large body of opinion that contends that artificial intelligence applications, especially expert systems, are the principal ways in which the expansion will take place. An indication can be found in the growing availability of easy-to-use software, especially, but by no means only in the microcomputer field. This has come about at least partly because the space is there: expanded memory means that the programme can store all the elements of a dialogue with the user and lead him or her through the steps necessary to carry out the desired process. The user no longer has to put up with a cryptic message giving an error number when something goes wrong.

A second hardware trend is in the area of mass storage. The main memory of the computer is where the programme actually runs, but it will be read into the main memory (in general) only when it is desired to run it. For the rest of the time it will stay on hard disk, diskette or tape storage. All these are magnetic media. The last of these is very cheap but very slow, the first is fast but expensive and the third is in between, and all thus depend on storing information in the form of electrical charges on the surface of the disk or tape. All are likely to be replaced very shortly by optical disk (laser disk) storage. Here the information is etched onto the surface by a laser and read by another. The information cannot be lost through magnetic interference and has a "life expectancy" of about seven years.[15] Already available are CD-ROMS. The size of an audio compact disc, they can store around 600 MB each (i.e. the equivalent of 1000 to 15000 floppy disks.[16] They cannot be written to by the normal user: they have to be pressed in a factory, analogously to records. They are thus best suited to large standardized databases of which copies can then be cheaply distributed, such as encyclopaedias. However, discs that can be written to once are now becoming available, and a 12 inch disc of this kind can store between 1 and 4 gigabytes (1000 to 4000 Megabytes). The availability of optical discs that can be erased and written on many times is still a couple of years away.

The design of hardware specifically for expert systems applications is another development. This occurs principally through the design of so-called artificial intelligence workstations. The term workstation is widely used and little defined: it occurs most often in the description "engineering workstation" and "office workstation". It usually means a computer with networking capabilities constructed or adapted for a single-user specific field of work. An office workstation might have telephone and document facilities while an engineering workstation would have graphics design facilities (Sometimes the term workstation is applied to a computer terminal with limited storage facilities).

An AI workstation usually seems to have (a) built-in languages (such as LISP, PROLOG or Smalltalk-80, (b) high-resolution screen, as well as a fast processor and lots of memory (RAM and hard disk) and networking facilities (usually Ethernet and often other possibilities also). The design of the microcomputer is often adapted to words of the particular language used, and in some cases the processor itself may be a hardware implementation of the language (always LISP, so far). The high-resolution screen is intended not for graphics as such. Development of AI applications usually involves looking at text (although one system marketed by Texas Instruments for process control provides facilities for working with diagrams of the factory process in question.[17]

The screen having such high resolution (the typical range is 1024 x 800 pixels, going as high as 1280 x 1024) can display more text at any one time, usually with the facility for "windows", by which several separate programs or program sections, sets of data, and dialogues and results can all be seen simultaneously. The developer of the expert system will usually also find other powerful tools, such as special software for designing, building and testing expert systems. Costs vary from £7,000 to £65,000.[18/]

A second hardware development is in the construction of specialized processor chips which embody expert system shells or constructs (rather than just AI languages). Work of this kind is being carried out at AT & T Bell Laboratories, where a chip implementing a "fuzzy logic" expert system is claimed to be 10,000 times faster than conventional systems.[19/] The benefits of having the system in hardware rather than software are clearly considerable in terms of speed. However the design of expert systems can hardly be said to be far enough advanced for chips to become widespread soon.

In general, the consequences of hardware developments are that enormous cheap storage as well as faster processors are opening up the field of expert systems for possibly very rapid growth. The knowledge base can be large and, being online, can be quickly accessed. Moreover, the expert system can be reasonably portable: a computer system with a few optical disks may encapsulate a whole lifetime or several lifetimes of individual experience of particular problems.

However, this will not come overnight. With past progress in software and present progress in hardware, the preconditions are now in place. A system can analyse the rules supplied and answer questions on that basis, but the information must still be entered: the present difficulty is to find efficient ways to transfer expertise from the expert to the system. This can be done in several ways. Two of the obvious ones are time consuming: the expert can be asked a series of questions and the answers recorded. If the questions asked are exhaustive enough a full database can be built up in this way of what the response should be to a particular combination of circumstances or preconditions. The second approach is to get the expert himself to sum up his knowledge in a series of rules that encapsulate it. Without careful guidance, however, the expert might tend to supply only his "mainstream" knowledge, and the nuances, intuitive judgements and unstructured experience characteristic of the human expert might be lost to the system being constructed. If a "knowledge engineered" interrogates the expert to extract the rules, he or she can be better off not knowing the subject in question: otherwise vital information can be overlooked as being too obvious.

5. The actors

The forces shaping future development of these systems include:

(i) Computer manufacturers
(ii) Software manufacturers
(iii) Systems companies
(iv) Non-computing companies
(v) Specialist information companies
(vi) Government agencies

All the major computer manufacturers now have a presence in the artificial expert systems field. As noted they often use these techniques in their own work, either in planning, configuring or diagnostics. Involvement in national programme of research is another way in which some have entered the field. The products offered include software environments, expert systems shells and AI workstations. The big mainframe manufacturers have been slower to make an impact in the market than other computer or software manufacturers, often because they cater for an evolutionary market (the traditional data processing users) and cannot move too far ahead of them. Smaller companies can be more agile. However, they may lack the resources needed to bring expert systems developments to marketable levels. It is the large companies such as IBM who have this kind of R & D capability, and who can persuade potential users of the maturity of expert systems as a workable tool. As against this it should be noted that, increasingly, it is the end-users in a company who are determining computer policy.

Software companies typically write and sell a computer programme package which contains the expert system shell, a query system, some database management capacity (to hold the knowledge base) and perhaps some component that allows for the easier construction of the knowledge base. The typical software company plans to sell a number of its systems, this resulting in a more or less generalised system which is not tied to one particular application. If it is a microcomputer based system the potential market may even be numbered in many thousands. In this case marketing will have a crucial role to play.

Still in the field of microcomputers, the race to establish standards in expert systems has not yet begun, but it is more important in this consumer-oriented and suggestible sector than elsewhere. A standard, at least for microcomputer based expert systems will be established not by an international committee but by the competitive forces of a market which has not yet been studied in any detail. Since the most difficult problem now in the construction of expert systems is the extraction of the knowledge from the human expert, the winner in the software race may be the company who produces either (a) an easy-to-use dialogue package for construction of the knowledge base or (b) a standard format knowledge database handling package.

A standard is important for several reasons. Firstly, and obviously, it will mean success for the company which establishes it. Secondly, it will release the larger market that has been waiting for a standard to be established. Thirdly, it will encourage the production of a number of third-party products. These may be extra software or software/hardware packages that are supposed to make the original standard product easier to use, or they may be sets of knowledge in different areas. All will be advertised as being "x-compatible" or "meets the x standard", thus further promoting the sale of x, the standard.

Looking at present software on the market, it can be divided into that available for mainframes, for minicomputers, and for microcomputers (even if these distinction and especially that between the last two, are becoming blurred). One source of information[10] gives from a total of 17 packages in the United States thought to be suitable for manufacturing applications, only one was for mainframes, four for microcomputers, and the remainder, 12, for minicomputers. Of all the systems, only two were given as intended for specific applications, (electronics and medicine) with the remainder being of general application, at least by implication. By contract, a survey[21] in the United Kingdom shows that expert systems (as distinct from languages intended for artificial intelligence applications) are more generally available. Of a total of nine systems, three were for mainframes, three for micros, one for minis and two for both micros and minis.

The third major group of actors is that of the systems companies, who rather than marketing a finished product, will construct a computer system (perhaps supplying the hardware as well as writing the software). Such custom-built systems are likely to be more successful for the immediate future in the field of expert systems than in other fields. This is because expert systems contrasts markedly with accountancy or inventory control, being a good deal less fully defined as a discipline. The average business can choose from many available software packages to carry out the payroll: at least one of the packages may have the flexibility to cope with the requirements of the particular business. But this is less likely to be the case with expert systems, not so much because of the uniqueness of the reasoning needed as of the specificity of knowledge formulation. Requirements for the near future as new applications spread, are not likely to be standardised. Nevertheless, some of the systems houses are likely to become centres of accumulated experience in a way that the software manufacturers will not. The large number of firms will militate against standards developing, but the presence of many small firms may give continuing impetus to creativity and technical progress.

The fourth group of actors is that of the non-computing companies, who are in neither the software nor the hardware of the knowledge business. These are companies whether in industry or services who are anxious to apply expert systems to their own operations. It has been pointed out that many companies now entering the field are being extremely discreet about their activity, and that the reason is that they feel the new techniques will give them a competitive edge against other companies. This means that technical development achieved in experts systems within these companies are not going to be rapidly diffused. On the other hand, the fact of an increasingly strong vote of confidence in expert systems (or at least in the future of them) means that a cumulative effect is likely. A possibly more open development will be the supplying of expert systems with the purchase of capital goods. Covering correct use maintenance and diagnostics and repair, expert systems could replace not only traditional technical manuals but also much of the human expertise at present provided as support services.

Specialist information companies form the fifth group of actors. They include, in particular, both general and specialist publishers, news and information companies, market intelligence and abstracting companies, database companies and the like. Many have already moved into the software and data communications fields: some have considerable experience in the field of data input, and data storage. They are in some cases in a good position to exploit expert systems in making their databases more analytically-oriented: the setting up of new inquiry systems which would allow for "intelligent" searches of a database of abstracts or of an encyclopaedia. The skills of these companies can also come into play in the incorporation of knowledge in new areas into expert systems.

The final group of actors is that of national governments. The impact of Japan's fifth generation computer project has been widespread. At first, the effects were most noticeable in the hardware field, with collaborative research between and among European and United States manufacturers being entered into. The push for co-operation was in response to what was seen as a Japanese challenge. The challenge was seen in the increasing penetration of U.S. and European markets by Japanese products, a process which has continued and which causes friction between Japan and its trading partners. But the fifth generation project raised anxieties about the long-term effects of the competitiveness of Europe and the United States in many if not most fields of manufacturing, not just in the fields of microelectronics and computers. The Project could be seen as an attempt to raise modern technology to a qualitatively different level, especially because of the stated areas of application, which included the areas of inference and knowledge-base sub-systems.[22] (Prolog was adopted as a language for artificial intelligence applications in the project).

The Japanese example was therefore followed, if initially more slowly, in both the United States and in Europe. Notable examples of United States intiatives has been the Strategic Computing Programme of the Defence Advanced Research Projects Agency, the Microelectronics and Computer Technology Corporation (MCC) and the Semiconductor Research Corporation (SRC), all of which are supporting research in expert systems. The latter two are in fact industry co-operatives, formed by large, well-established United States firms anxious to pool research or to support joint research on the new computer technologies.[2/4]

In the European Economic Community, the ESPRIT Programme was launched to fund co-operative, pre-competitive research in informatics technologies. Six main areas were focussed on: advanced microelectronics, software technologies, advanced information processing (including artificial intelligence and knowledge based systems), office systems, computer integrated manufacturing (CIM), and infrastructure.[23] A total of 1.5 billion ECU (of which the Commission of the EEC provides half) is used to fund the research. Research in knowledge based systems (but not expert systems per se) is supported by ESPRIT in France, the United Kingdom, Ireland, Italy, the Netherlands and the Federal Republic of Germany. As well as this, several individual EEC countries have their own national programmes in this field of information technology, such as the United Kingdom, France and the Federal Republic of Germany.

The EUREKA programme is a joint research and development effort which involves 18 European countries. It includes not only the EEC countries but also Norway, Sweden, Finland, Turkey, Switzerland and Austria. The programme includes technological advances in all areas not just in informatics. Nevertheless, of the projects so far announced, four are in the area of expert systems (with another two in closely related areas). They include the following projects:[24]

(a) Mentor: an expert system for dealing with major plant failures and security control. The participating countries are France and Norway, with interest expressed by Germany and Italy. The project will cost 30 million ECU and last for four years.

(b) Prolog Tools: Development of software tools aimed at expert systems. Belgium, Federal Republic of Germany and Switzerland (Commission of the European Communities) 2 million ECU, three years.

(c) Crop Management Expert System: Development of a range of expert systems software and ancillary hardware for use in crop management. Netherlands and United Kingdom, 0.6 million ECU, 3 years.

(d) BD II: database for distributed expert systems or low-level computers, France, Spain, (Denmark) 20 million ECU, 5 years.

(e) Paradi, automative production management system using AI developments. Belgium, France, Netherlands, Switzerland, (Federal Republic of Germany, Italy, Commission of the European Communities), 30 million ECU, six years.

(f) Galeno 2000: Automatic non-invasive medical diagnostic equipment based on new sensors and AI. Denmark, Spain, (France, Netherland, Switzerland), 60 million ECU, three years.

The latest plans for the CMEA countries include a five-year programme co-ordinated by the International Committee for Computer Engineering at the USSR Academy of Sciences.[25] This programme is directed towards fifth-generation techniques and will have activities in the areas of:

- VLSI
- Parallel and multiprocessor architecture
- Operating systems to support logic programming
- Problem solving
- Expert systems

6. Future prospects

Estimates are available from various sources of the possible market size for expert systems, or for artificial intelligence products in general. The extimates vary widely and without full definitions of the concepts used are only useful as broad indicators. Even the estimates for the present size of the market are very diverse.

One estimate is of a $1,600 million market by the end of the decade, including hardware, software and services, with the 1985 value being given as $342 million. The shares of the different components in the total would change to some extent, with software rising from 40 per cent to nearly half by 1989. Hardware sales would also increase their share from nearly a quarter to 30 per cent by 1989.[26] This would imply that services would decline from around 35 per cent to just over 20 per cent by 1989.

Another estimate gives a market value of $220 million 1985, with a projected $780 million in 1988, then steeper growth to $2,400 billion in 1991 and an even sharper growth to $8,535 million in 1993.[27] The present situation is seen from a different point of view by another estimate giving the 1986 market as $1,000 million in 1986, for artificial intelligence as a whole. The hardware share is given as 49 per cent, with aritificial vision systems 25 per cent, expert systems 13 per cent, national language programs 6 per cent, voice recognition 4 per cent and AI languages 3 per cent.[28]

These contrasting figures point as much to defitional difficulties as to different assumptions. The distinction between services and software is in fact a difficult one to draw. It is true that a LISP interpreter or an expert system shell can be bought by mail order for a few hundred dollars, and the purchaser may well wish to experiment on his or her own. But the person or company serious about expert system development will usually want support and training, even in an informal way. Some vendors themselves fell that in selling expert systems software they will also need to provide a lot of support, because of the early stages at which the discipline is at present. Hence, expert system software (and hardware) sales will have to include a greater degree of implied service than software and hardware for other purposes. Such considerations also suggest that services sales per se will be important also.

Market estimates are only part of the story, since the figures refer to what is traded. But expert systems development is underway within companies and institutions, this activity being subsumed in their overall figures. Very often, this is done deliberately: the point was made earlier that the activity is being kept secret by companies in order to maintain their competitive edge. However, some would suggest that the secretiveness can also cover embarrassment at a lack of success. Nevertheless, it has been estimated that over half of the "Fortune 500" companies in the United States have research projects in artificial intelligence.[29/]

Not all observers of expert systems are convinced. Some doubt that expert systems can really replace human expertise. Even if they could, would they be accepted? And can they have a commercial impact? One survey describes the XCON system referred to above as the only expert system to have "a genuine commercial impact" out of 43 systems surveyed in the United Kingdom and the United States.[30/]

The exaggerated promotion of the expert systems idea, usually in connexion with the marketing of some product, has been remarked upon as a danger, since it will arouse excessive expectations. The resulting disappointment when the system is found not as easy to construct or as useful in operation may have the effect of discouraging future efforts. The enthusiasts for expert systems may be more the technical staff of a company than the operational or commercial staff, yet it is only when the latter are convinced of the benefits that success is arrived at. A promising approach may therefore be to build in expert system techniques into traditional computer applications (such as is being done with CAD/CAM).

Certainly exaggerated claims for products can be made, and unreasonable expectations aroused. The greatest pitfall is to underestimate the work involved in the construction of a system. The difficulty is not only in the methodology, and in the transfer of knowledge: it is also the selection of a problem amenable to treatment in this way. It has been suggested that expert systems work best when the domain is clearly delimited, i.e. that the "boundaries" of the subject area are well-defined.

Nevertheless, any recognizable indicators point to continued growth in expert systems. The number of hardware and software products is increasing rapidly, both from small new companies and traditional computer manufacturers. The level of activity in expert systems within non-computing companies, while not as easy to measure, is certainly growing quickly. The increasing emphasis in public policy programmes is a third indication. Fourthly, the technology exists: at least for more straightforward rule-based systems, the logical and software issues have been under examination for over thirty years. Fifthly, the hardware is available and inexpensive: researchers do not have to compete with others for access to scarce computer resources. Finally, there is the more general consideration that technological change is itself creating the market: as knowledge expands, diversifies and specialises, the need for expert systems, to master and diffuse this knowledge, will continue to grow.

7. Implications for developing countries

It is already widely recognized that the influence of informatics technologies will be such as to transform the structure of industrial production, as well as of society generally, in the years to come. However, the likely effects of expert systems developments, especially for developing countries, have not been studies in detail, although some analyses have been made. What follows is a brief overview of some of the issues.

Within the software industry, there may be a tendency for the relative position of developing countries to deteriorate in the short term. This is because existing applications software approaches, in which the developed countries have a very dominant position, can be upgraded through the incorporation of expert systems features. Thus, database or CAD/CAM systems can be made easier to use, and these are already areas in which developed country producers have significant strengths. The market opportunities for developing countries in newer areas directly related to expert systems appear at first sight to be limited. This is for several reasons. Compilers and interpreters for AI languages already constitute a very competitive field. Expert system shells are perhaps easier to produce but for this very reason competition will also be considerable. Prices can be expected to fall.

As for expert systems themselves, it should be recalled that their basic purpose is to transfer and diffuse expertise. To the extent that human experts are in short supply in developing countries, the construction of expert systems is more difficult. The successful production and marketing of expert systems will therefore have to concentrate on areas in which developing countries have particular advantages.

This means that some aspects would be particularly suitable for co-operative activity among developing countries. Expert systems could be developed which convey the accumulated successful expertise of one country in a particular subject area. Health systems, agriculture, industrial process control, and education are some of the may possible areas where, though expert systems, experience can be shared, and the accumulated skills in these fields disseminated over other countries.

There are however possibilities also, in the longer term, for methodological advances in expert systems, especially in the promising areas of knowledge base construction and handling. The interface with the human expert, in order to formalize the (often apparently intuitive) expertise into a series of applicable rules, is a most important areas where much remains to be done. This field of research is relatively open and may offer attractive opportunities to developing countries.

Outside the software field, the impact of expert systems can be expected to be extensive. Two contrast in effects can be suggested. Firstly, the incorporation of expert systems will follow that of microelectronics into most aspects of economic activity. Just as capital and consumer goods contain an increasing amount of microelectronics control capability, it can be expected that expert systems software and knowledge bases will make equipment more and more flexible and adaptive. The first effect will therefore probably be that industry, and economic activity generally, in developed countries will make further productivity gains, increasing its responsiveness to changing conditions and reducing the labour content of its products, especially reducing high-cost skilled labour inputs. These considerations point to a short term gain for developed countries, because it will be they who produce the new expert systems technologies and who will have first access to them. The significant in-house development of expert systems by non-computing companies, as well as the interest being shown by governments, reinforces the conclusion that it is mainly in the developed countries that the first benefits of expert systems will be found.

However, the characteristics of expert systems, as a computer-based technology, are such that developing countries may well be able to recover any ground lost before too long. This is because the technology is relatively portable and inexpensive, meaning that its diffusion into developing countries may be relatively rapid. Furthermore, expert systems being essentially ways of transmitting skills, means that they can contribute directly to filling a crucial need of developing countries' industry. The skills shortage may be significantly reduced if capital goods are supplied with, or else embody, expert systems, which advise in the use of the equipment and which diagnose faults in its operation. Competition betweeen suppliers may encourage such a tendency.

In general, the developing countries will have to take account of trends in this area, as they have done in other branches of informatics. (Singapore already has a goverment-supported programme in artificial intelligence).[31/] The impact of microelectronics, telecommunications and other hardware fields will include wider developments in software, and expert systems have several characteristics which make them extremely important for developing countries' industrialization.

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