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Report on the Workshop on Industrial Applications of Expert Systems in Developing Countries 23-27 November, 1992

Organised By
United Nations Industrial Development Organization
in Conjunction with
National Centre for Expert Systems
Hyderabad, India

A Report
December 7, 1992

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1. INTRODUCTION

The Workshop on Industrial Applications of Expert Systems in Developing Countries was held in Hyderabad, India, from 23 to 27 November 1992. It was attended by 25 participants, five of them from countries outside India. The meeting was organized by UNIDO in conjunction with the Institute of Public Enterprises, Hyderabad, and hosted by the National Centre for Expert Systems and the National Information Centre, Hyderabad.

The aims of the meeting were to:

(a) Exchange information and experience on the potential industrial applications of expert systems in developing countries through prototype demonstrations and discussions on prototype expert systems and country papers prepared by the participants;

(b) Establish modalities and scope for exchange of expertise in the field of industrial applications of expert systems;

(c) Identify high priority needs and methodologies for R and D to be undertaken by participating country experts for application in interested countries;

(d) Provide the basis for further development and elaboration of a knowledge-based decision support system for the formulation of scenarios on competitiveness strategies currently being developed as a prototype by the Instituto Technologico de Monterrey, Mexico.

The workshop itself was an exercise in technical cooperation among developing countries (TCDC), having the potential to promote cooperation in developmert and use of expert systems between China, India, Mexico and Republic of Korea.

The programme (see annex 1) features presentations by Indian and overseas participants, demonstrations of their expert systems prototype and new shells, demonstrations of commercially available shells and technical visits to the National Information Centre and a software development park.

2.ORGANIZATION OF THE MEETING

Opening of the meeting

Participants were welcomed by Prof. E. Balagurusamy, Director of the National Centre for Expert Systems (NCES). Following an introduction by the head of the UNIDO delegation, the workshop was formally opened by Mr. T.L. Sanker, President of NCES and its parent organization the Institute for Public Enterprises (IPE).

Election of officers

The workshop elected Prof. E. Balagurusamy (India) as Chairman, and Dr. Carlos Scheel (Mexico) as Vice Chairman.

Agenda

The following agenda was adopted:

Opening of the meeting
India's capabilities in AI and ES
Indian ES prototypes and shells
China's capabilities in ES
Republic of Korea's capabilities in ES
Potential areas of application of expert systems
in developing countries
A competitiveness strategies system (Mexico)
Presentation of commercial shells
Consideration of the final report
Closure of the meeting

Closure of the meeting

A concluding session was conducted at the end, in the afternoon of 27 November, 1992 to review the contributions made during the meeting and recommend appropriate suggestions and actions for UNIDO's consideration for organizing similiar cooperative events. The concluding session was chaired by Prof. E Balagurusamy and Mr. Peter Ellwood of UNIDO assisted the chair.

3. GLOBAL VIEW OF ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS

Reviewing the status of expert systems, Prof. Balagurusamy placed them in the context of artificial intelligence (AI) and information technology (IT). IT had emerged as the industry of the 1990s, he noted, and AI was one of its fastest growing areas. Its main goal was to make machines that could think and perform tasks that were indistinguishable from that of the human mind. Since the impetus given by the fifth generation project in the early 1980s to build computer systems with intellectual interfaces, AI had become a matter of national concern for many countries. AI made a remarkable move into industry and business; its most significant innovation was the knowledge-based approach to solving problems.

The global initiatives in AI technology had taken off in 1982 with Japan's Fifth Generation project, followed by the UK's Alvey programme, Europe's ESPRIT and the United States DARPA Strategic Computing project. Imaginative IT researcher were already looking into future technologies, such as Japan's Sixth Generation, which would aim to analyse the human brain, apply biochemistry, develop biological chips, optical computing and analyse communication processes and psychological effects.

Today, AI was playing a major role in reshaping traditional methods of how organizations were managed. It constituted not only a challenge but also an opportunity to organizations and their executives to exploit its potential for increasing productivity and competitiveness. Expert systems, he suggested had been the most commercially exploited area within the realm of AI.

Dr. Balagurusamy proposed a working definition of an expert system as a computer programme that relied on a body of knowledge to perform a complex task usually performed by a human expert. Whereas traditional programmes calculated using numbers, expert systems used knowledge. Applications were found in banking and insurance, industry, commerce and services, public sector organizations and others. Those in industry included process monitoring and control (process supervision, process control and reporting special situations), design (configuration, factories, product design), diagnosis (trouble shooting, maintenance), planning (design of logical functions, project planning), consultation services (customer service) and training. ES tools could be built using programming languages such as LISP or PROLOG or knowledge engineering tools such as KEE and ART. Of the two, programming languages offered more flexibility but required the developer to design the knowledge base and implement the inference engine to access that knowledge.

Developing countries could not afford to be silent spectators in any aspect of AI. Its economic potential and widespread benefits should be fully exploited by them. These countries were searching for alternative strategies and policy instruments that would enable them to respond more effectively to the changing global economic environment. Strategies for gaining, or maintaining, access to new technologies, especially those involving AI, were vital to successful strategic response.

Many developing countries had initiated in a limited way their own research programmes. They had specialized centres or institutions for AI research and were encouraging research and industrial organizations in their efforts to develop AI-based systems.

R and D in expert systems

The R and D work on expert systems undertaken in academic institutions was represented in a contribution by Prof. R. Sadananda reviewing ES-related theses submitted to the Asian Institute of Technology, Bangkok, Thailand. He noted that a number of financial institutions in Thailand were looking to expert systems for help in decision making, for example the Bangkok Bank. Stock brokers were also considering them. In the service sector, Thai Airways had taken the lead with a flight operation system that relied on for route planners and operations. The work was being undertaken by a new private company run by enthusiastic young professionals.

In the steel rope industry an expert system used blackboard architecture to make decisions on machinery maintenance. In the chemical sector, another system will load chemical tanks. Applications of neural network applications in industry could also be expected. A common feature of industrial applications was the need to integrate AI technology with mainstream software engineering, Prof. Sadananda noted.

Selecting expert systems

Reporting on work in preparation for an expert system to assist in the selection of expert systems, Prof. Sadananda divided expertise, i.e. potential applications, into three broad groups: (a) where a few experts had good knowledge (a good case for ES); (b) where there were no experts (an ES was needed, but very difficult to build); and (c) where everyone knows how to solve the problem (no case for ES).

Most organizations developed expert systems using shells purchased at a cost ranging from nearly nothing to over $100,000. Developing an application package from scratch was, in his view, the equivalent of developing one's own spreadsheet. The factors to consider in purchasing shells comprised (1) the nature of the problem (the domain and the application type); (2) the human aspects (end-user interface, developer interface, i.e. the domain expert, the knowledge engineer and the system developer); the technical aspects (system interface, inference engine, knowledge base, data interface); and (3) economic considerations.

User requirements would vary considerably between those of clerical staff, domain experts, systems programmers and AI professionals. ES shell evaluation was also a process of reconciling project characteristics and shell characteristics-its goals, scope, budget, development environment and composition and background of the development team. As with software, evaluation involved more than a demonstration; emphasis should be on critical capabilities. Simplistic use of checklists that counted available features may prematurely eliminate a suitable product for lack of features that might not actually be needed. Detailed

judgements by users and experts should be combined with objective measurements. These would focus on the knowledge base, methods of certainty measurement, the inference engine used, the search strategy, developer interface features (command language interpreter, automatic error correction, history of commands with side effects, documentation and tutorial), editing and debugging tools, the presence and design of an explanation facility, the availability of graphic and windows, mathematical features, the method of conflict resolution, the code generator features (e.g. the availability of a cross compiler), and the system interface compiler. In addition a critiquing system was important for improving the quality of the knowledge acquired by helping to doubt, trap and repair expert judgement. Even acknowledged experts had blind spots; knowledge engineers may also have blind spots in choosing experts and interpreting knowledge. Critics could be passive (spelling and grammar checkers) or active, e.g. those designed for medical decision support systems.

Only the most expensive expert system shells offered a comprehensive collection of all capabilities. With over 150 shells on the market, tool choice and problem selection were therefore important. Many shells were offered by vendors without track records, Prof. Sadananda warned.

4. INDIA'S CAPABILITY IN ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS

Reporting on the status of India's artificial intelligence and expert systems capabilities, Prof. Balagurusamy said that India had at its disposal all three key elements needed for progress in AI and ES: a sound scientific infrastructure, a thriving electronic industry with indigenous R and D capability, and a recognized information technology industry. The IT industry comprised over 300 companies and the vast domestic market combined with recent liberalization policies was attracting many multinational firms to invest in it. Over 30 per cent of all IT activities were accounted for by software, which was also one of India's fastest growing exports. According to the World Bank, their value should exceed $1 billion by 1996. Reflecting this, the Government had established a network of software technology parks (STPs), so far in six cities, to provide infrastructure facilities, develop and export software and software services, and train and/or orient professionals in software technology and software engineering. The STPs acted as nodal agencies for all Government approvals and provided high-speed communication facilities.

Other components of India's IT effort included computer manpower development, programmes of IT development and applications projects, promotion of large public sector corporations exclusively devoted to development and promotion of IT, and provision of data communication facilities.

Experience in AI

Spurred by the Government's Fifth Generation Computer Systems Programme in 1985, a project in the area of Knowledge-based Computer Systems (KBCS) established nodal centres and activities in eight areas: speech recognition (TIFR, Bombay), pattern recognition (ISI, Calcutta), expert system technology (IIT, Madras), parallel processing (IISc, Bangalore), natural language processing (NCST, Bombay and C-DAC, Pune), expert systems in Government (Department of Electronics (DoE), Delhi), AI in education (NCST, Bombay) and technology transfer (NCES, Hyderabad).

In the expert systems area, IIT Madras focused on development of intelligent information systems for non-urban usage (medical diagnosis and family health), expert systems for engineering applications (crane design, product formulation, and selection of drill tools in process planning) and development of expert systems tools (IITMRULE--a rule-based shell in C with a library of C functions). Several of these developments were described and demonstrated at the workshop.

The DoE nodal centre responsible for decision support systems for the Government had complete expert systems for income tax assessment, India's export-import policies and civil service pension rules. Under development by the National Informatics Centre are expert systems to assist operation of India's welfare schemes and a nutrition diet programme.

In the remote sensing area, the National Remote Sensing Agency in Hyderabad has initiated ES development projects in wetland mapping, fault diagnosis and maintenance, site planning, soil classification and land form identification.

The work of the National Centre for Expert Systems (NCES) focuses on helping industry and governments in the application of AI technology and tools, particularly transferring ideas and skills to the people in those sectors. The Centre's activities include education and training, joint projects, consultancy, and development of application systems. Short-term executive development programmes are also offered. Software/knowledge engineers are trained to decide the suitability of applications and the various tools available, to develop the systems using both language tools and expert systems shells and to appreciate the issues involved in building and using expert systems.

Another government institution, the Electronics Research and Development Centre had developed a LISP interpreter, a graphics editor and several expert systems shells. Using these tools ERDC's applications are in industry, health care, agriculture and education.

A comprehensive report on India's initiatives and capabilities in the Applications of AI and Expert Systems is enclosed. of ES tools and applications recently developed in India is shown in annex 4.

5. EXPERT SYSTEMS SHELLS AND APPLICATIONS

Expert system shells and applications, which were presented by each participant, are summarized below. Most presentations were also complemented by demonstrations.

BLUE Systems (India), New Delhi, India

Recognizing the fact that top-notch domain experts did not have the time and/or wish to cooperate, BLUE Systems has used the concept of selecting a core domain consultant whose base model was used as an input for the system model. However, to obliviate problems based on a single expert opinion, the Company took the model to other domain experts requesting comments and improvements. In addition to that, the Company believes that the expert system development should be controlled by the sponsoring agency via a project plan given by the developers. Adding extraneous points of control in this process are not value-added activities and can cause slippages in the schedules.

Prototype expert system on privatization

Privatization, in its diverse implementation is a key strategy adopted by many countries to effect the shift from public ownership of economic assets to market-based enterprise systems. An expert system for privatization incorporating expertise and experimental learning across developing countries into a multidisciplinary, model based system can enhance the quality of policy making in the area of privatization in developing countries.

The system model operates at two frames. Frame I considers privatization from a macro-level (national and sectoral) perspective. This frame considers strategic issues on privatization such as the government's objectives for privatizing, the utilization of resources generated from privatization, the sectoral objectives under which public sector enterprises operate in addition to an evaluation of the public sector enterprises themselves. Frame I then recommends a national/sectoral privatization strategy and alternative annual disinvestment plans.

Frame II is an enterprise level evaluation of the privatization potential. This frame undertakes a comprehensive evaluation of enterprise variables concerning performance, enterprise objectives, competitiveness of the sector, organizational structure, strengths and weaknesses, and potential for improvement. In addition this frame analyses the enterprise level privatization potential in the context of the national strategy and arrives at a privatization recommendation for the enterprise.

Prototype expert system on environmental impact assessment

The increasing pace and scale of worldwide industrial development has led to environmental degradation and consequences such as acid rain, smog and ozone layer depletion. In the last few years, a better understanding of the environmental impact of industrial development has led to a global concern for environment conservation and ecologically sound industrial development. The expert system on Environmental Impact Assessment will promote environmentally sound decision making at the planning, project design and implementation stages of industrial development and increase the availability of environment-related expertise in developing countries.

The system is modeled in three Frames. Frames I and II assess the environmental impact of a single industrial enterprise while Frame III assesses the environmental impact of an industrial sector. Frames I and II use a large information base of data about the industry, polluting substances, geographical and climatological factors in addition to knowledge base of transport and effect models to provide a pollution assessment and industrial hazard assessment for the industry. Frame I, in addition provides a locational assessment for the setting of new industry.

Frame III uses environment and industry information, to assess the large scale environmental impact for an industrial sector. The system can be used by industrial users and environmental organizations to conduct an impact assessment and by policy makers to evaluate environment regulations, locational assessment criteria and industrial safety norms.

Prototype expert system of international joint ventures

International joint ventures are being used by an increasing number of enterprises across the world, as a strategic option to reduce uncertainty and risk, to promote internationalization of enterprise and technology transfer and to gain access to market

and resources. International joint ventures have been extensively used in developing countries as a means of technology transfer and in developed countries as a means of access to large and growing international markets. However, joint ventures are a complex form of strategic alliance between enterprises and are often prone to conflict and instability. The expert system on international joint ventures will assist decision makers to evaluate joint venture proposals and help in joint venture design and implementation.

The system evaluates the objectives and organizational capabilities of an enterprise seeking to setup an international joint venture and recommends the best strategic alliance option for the enterprise. The system then helps the enterprise select or evaluate a country, select or evaluate a joint venture partner, and select or evaluate a technology or product. The system also evaluates the strategy objectives of both partners and recommends share of ownership and control for the joint venture. In the post-entry module, the system recommends a design for the joint venture in terms of organizational structure and systems. The system also recommends a market strategy for the joint venture. The implementation module evaluates the performance of the joint venture after implementation and recommends strategies for conflict resolution and performance improvement.

The system can be used by enterprises in developing countries seeking joint ventures for technology transfer and by enterprises in developed countries seeking access to developing country markets. The system can also be used by planners and policy-makers to evaluate technology transfer and foreign investment policies.

Prototype expert system on environmental scanning

In a competitive business environment, coupled with increased uncertainty of macroeconomic conditions, the need for an enterprise to carry out a continuous and effective monitoring of the environment is of strategic importance. Environmental Scanning can help an enterprise identify threats and opportunities and is an important prerequisite to corporate planning and effective competitive strategy. An expert system for environmental scanning would be able to effectively model the complexity of the environment and capture the linkages between environmental variables.

The system evaluates a large number of environmental variables, qualitative and quantitative, in the macroeconomic, political, sociocultural, regulatory, competitive and ecological environment of the enterprise and uses a knowledge base of interpretative rules and interlinkages between variables to generate an environmental scenario for the enterprise. The system can be used by enterprise decision makers in strategy formulation and by policy makers to evaluate the impact of policies on business enterprises.

National Centre for Expert Systems, Hyderabad, India

Knowledge-based system for industry sickness prediction

Corporate sickness is significant problem in market economies. In developing countries like India the problem of sickness is likely to grow worse. An early warning system which signals the probable sickness or abnormal functioning of the enterprise to the concerned parties would be very useful. Such a system can be built as an knowledge based system for a given industry or an enterprise within it.

The problem-driven approach analysis has been used to analyze the problem domain to build a conceptual model for problem solving and implementing it as a prototype. The enterprise is viewed by the expert as a system consisting of functional subsystems that are integrated by the corporate management subsystem as a whole. The goal states of the sickness analysis was defined to fall into two categories:

- corporate management issues which are primarily related to profitability, reserve strength, and accountability, and
- tactical management issues which are primarily related to the functioning of the functional (marketing, finance, production and personnel) subsystems.

The input data consists of findings/observations based on the financial statements and other notes of the enterprise being evaluated. Derived data is arrived at by inferencing from the input data. Inferential knowledge is present in tasks dealing with interpretation and diagnosis. Using the rule formalism, the inferential knowledge has been formulated into rules.

The problem solving strategy initiates in diagnosis, but moves quickly to search for problems in the functional subsystems by looking into the input data. The search strategy used is backward chaining with rules that control reasoning within all the subcomponents of the diagnosis. The prototype has been built using Vpexpert which is a rule based expert system development tool. However, the prototype has to be expanded further by including more internal and external factors that would affect the functioning of an enterprise.

IIT, Madras, India

IITM-DESS diagnostic expert system shell

IITM-DESS is a tool designed and implemented for fault diagnosis of industrial equipment. This tool captures the expertise required to diagnose faults in the form of fault tress. It provides explanations for the repairs suggested and a comprehensive report of replaced parts, new parts for an associated database maintenance.

IITM-DESS provides a systematic way of organizing the experiential knowledge of a trouble-shooting expert, and allows the institutional usage of this scarce expertise in remote service areas.

IITM-DESS is an expert system development tool that has been specially adapted to deal with problems in the areas of fault localization, diagnosis and repair. Using this tool, it is possible to build diagnostic expert systems in any domain, provided the knowledge involved can be articulated by the domain expert in the form of fault trees. Some of the important features of IITM-DESS are as follows:

- Knowledge represented as fault trees
- Tree traversal with knowledge based backtracking
- Suspension and resumption of inference sessions
- Competence level checks of service personnel
- Dynamic loading of subtrees

IITM-DESS runs on IBM PC/XT/AT under DOS environments. It is developed using Turbo-C. The knowledge component of the IITM-DESS is specified in IDL (IITM-DESS Language), a language designed by IIT Madras.

Currently and in collaboration with the ALACRITY FOUNDATIONS PVT LTD, Madras, IITM-DESS is being used to develop an expert system for the diagnosis of servo stabilizers.

IITMRULE: a rule based expert system development shell

IITMRULE is a rule based expert system development shell that can be used to build expert systems in diverse domains.

Rule based expert systems can be developed using IITMRULE. The software essentially consists of three important modules and a database interface toolkit. The main modules are the interactive rulebase editor (KBE), rulebase compiler (KBC) and a user-friendly inference engine (KBS). Some of the main features of the software are listed below:

- An interactive program for creating or editing rulebases
- A rulebase compiler
- An inference engine with forward/backward chaining modes
- Confidence factors, for reasoning with uncertainty
- Explanation features like HOW and WHY
- Mutual exclusion metaknowledge for search space pruning
- Rerun facility
- Database lookup interface facility
- Callable external Pascal functions

IITMRULE runs on IBM PC/XT/AT compatibles under DOS environment. IITMRULE is implemented using Turbo-Pascal. The software is distributed in two 360 KB diskettes along with a user manual. Users pay a very nominal price to cover media copying and shipping costs.

IITMRULE is well documented, and the software is being distributed to interested users. Over 300 copies have been distributed all over India to educational institutions, research labs, industrial organizations and individuals. IITMRULE has also been distributed to participants of the various workshops conducted by the Nodal Centre on Expert Systems. IITMRULE also forms a very important course material for the expert systems course that is taught to graduate students at IIT, Madras. The popularity and ease of use of this software is emphasized by the

fact that, over 150 expert systems have been developed by workshop participants and students taking the Expert Systems course in diverse application domains.

IITMRULE is probably the most inexpensive expert system development shell being distributed (about Rs.400, as on date). The real cost benefits of the expert system developed using this, is dependent on the domain of application.

XCUTE: expert system for selection cutting tools

Manufacturing industries that produce different types of parts, use a variety of cutting tools (inserts) for their operations. Shop floor managers spend considerable time in selecting an appropriate toolholder-insert combination for each cutting operation. XCUTE is an expert system that aims at suggesting holder - insert combinations best suited for the user's requirements, thereby reducing the overhead time. The choice of a right combination is particularly important as it affects the quality of finishing and the cost of the cutting operation. XCUTE does not however perform a detailed and optimized selection of all tool features - it takes into account only the problem of geometrical compatibility with the work piece and differences between roughing and finishing tools.

An expert system for selection of cutting tools is useful, for the following reasons:

- Tool selection depends mainly on practical experience and stock availability, and often this choice cannot be extracted from handbooks, manufacturer catalogs and exact knowledge available in text books by the end user.

- Tool manufacturers put on the market several typologies of tool holders and inserts, so that choice of the best combination is not an easy task that can be done quickly.

- Production of new tool is practically continuous; so a system for an automated selection of tools that is frequently updated by the software specialists, is very useful.

- Codes designating tools confirm to a standard pattern. ISO codes comprise letters and digits occupying pre-fixed positions; while the non-ISO codes have different order.

XCUTE runs on IBM PC/XT/AT under DOS environment. It is developed using Turbo Prolog. There is an industrial collaboration programme with TVS Lucas, Madras to incorporate the knowledge relevant to the selection process. A research prototype has already been demonstrated.

Tsinghua University, Beijing, China

Diagnostic expert system shell (dess-th)
and its applications for mechanical-electric devices

DESS-TH is a rule-based system with two kinds of knowledge representation: the rules with two certainty factors to

represent the experience knowledge and the frames to represent the structure knowledge of devices. The inference engine is designed in terms of the positive and negative evidence principle and can deal with the uncertainty reasoning.

How to get the new evidences is one of the important techniques during the fault diagnosing. People always expect the tests with minimum cost to find out the disorders as quickly as possible. So several points have been considered.

To facilitate the user's operation, DESS-TH adopts chinese characters display with multi-window. All the functions can be easily selected under the guidance of the pop-up menus. The user can also complete some operations by using the prompt information guide.

A Radar Fault Diagnostic Expert System has been successfully developed using DESS-TH. Another application example has been the Linear Accelerator (SL75-14) Fault Diagnostic Expert System which is used for radiation treatment for the cancer patients. DESS-TH is developed by using the GCLISP with chinese characters and run on a PC.

Korean Advanced Institute of Science and Technology, South Korea

Stratplanner: a connectionist expert system for strategic planning

This paper presents a Decision Support System for strategic planning. The DSS called StratPlanner is based on the combination of neural network and expert system where neural network is used for a knowledge base. Utilizing neural network as a part of expert system has several advantages; robustness and learnability among other things. Robustness helps to guess an approximate solution when faced with unknown or unexpected situations. Learnability enables the system to extract the rules which provides a useful vehicle for automatic knowledge acquisition. For the strategic planning of production and market share of an electronic company, three models are used; BCG matrix, Growth/Gain matrix, and GE matrix. Two kinds of knowledge bases are constructed; neural network-based knowledge base and conventional knowledge base where neural network-based rules are extracted from the trained neural network. The current version of the system is a prototype coded entirely in C. An experiment is conducted for the strategic planning of an electronic company using four years data for seven electronic appliance products.

Instituto Tecnologico de Monterrey (ITESM), Mexico

Intelligent distributed information system for competitiveness strategies (INTELLICOM)

It is a geographically distributed competitiveness intelligence network built to support regional competitiveness strategies. It is a system designed to support: problem solving, planning processes and strategies formulation on a regional basis but with a global scope, based on the expertise and experience of a recognized network of experts on the field.

INTELLICOM is supported by the following technologies:

- Cognitive scenarios
- Group support systems
- Qualitative modelling and knowledge based systems
- Distributed knowledge based systems
- Sectorial competitiveness analysis
- Porter's competitiveness paradigm
- Sustainable development paradigm
- Systematic thinking approach

INTELLICOM is a cooperative sectorial intelligence network to support industrial policy makers, general chambers, specialized chambers, industrial groups and "global" companies.

The system developer explained that it from an ES technology standpoint it was a combination of low-technology systems, a standard data base, and a simple rule-based inference engine. What was now needed was to integrate three different environments that currently had to be linked manually. Although it lack a mechanism to compute a confidence level for the scenarios in relation to the quality of the information and group judgements, it could easily by used to test their sensitivity to changes in those inputs.

Requested for its opinion by the UNIDO Secretariat, workshop participants generally agreed that the approach of Instituto Tecnologico de Monterrey had resulted in an interesting collection of decision support systems, with some interesting outputs. It showed a way to manage decisions that would have to be taken with or without such systems.

Particular comments were User sessions would themselves be enlightening and re-use of the system in further sessions would give further insights, for example, in establishing the sensitivity of certain scenarios to changes in input conditions.

The general approach was a solid demonstration of how even complex domains with uncertain information could be modeled. Competitivity was treated systemically, enabling it to be applied in a variety of ways, e.g competitors behaviour, international competitive readiness, introduction of new products, introduction of new technologies, industrial sectoral strengths and weaknesses, firms' modeling through the chain value and fragmented industries modeling. The common aspects were identification of critical or relevant driving factors which were producers of the phenomenas main behaviour such as rivalry threatedness, buyer bargaining power, supplier bargain power and market planning analysis.

The model would be usable in India and other countries for similar problems at four different levels: national (for government ministries and planning commissions), subnational (e.g. province or state), regional, sectoral and enterprise level. Governments required information for policy interventions, the modifications for which should not be difficult to introduce. Moving the system to another country would involve generating new country-specific data but the basic model of Porter was generally applicable and well accepted. Moving to a different level would require a change of objectives, e.g. combinations of profitability and social welfare at the

sector or subnational level. There would nevertheless be applications of interest to Governments such as the competitivity of the automobile or electronics sector.

The approach would find itself alongside other decision support systems such as input-output studies, social accounting matrices and multiple regression analysis. Like them it may also depend greatly on the common sense continuously provided by the promoters and operators.

Another government use would be identification of successful firms with a view to their proactive promotion.

ERDC, Thiruvananthapuram, India

Expert systems for allocation and scheduling of transportation of coal

Steel Authority of India Ltd. (SAIL) uses higher grade imported coal for advanced processing of steel. Imported coal arrives at different ports and each steel plant takes coal from these ports. Each plant has a set of preferred ports.

Allocation of coal from a port to a plant depends on many factors such as quantity in stock at each steel plant, quantity available at each port, availability of wagons, availability of loading facility at each port, etc.

Everyday a co-ordination committee consisting of members from SAIL, port authorities, and railways meet at Delhi to finalize the allocation and transportation of coal from ports to plants. SAIL representative is compelled to make allocation decision within the course of the meeting which may last about half an hour or so. This places serious constraints on the SAIL representative and the quality of the decision taken leaves much to be desired.

This Expert System is used by SAIL to prepare a limited number of most probable scenarios and thereby make the SAIL representative better equipped to make decisions on allocations at the co-ordination committee meeting.

The expert system approach is the only possible one in this case since the problem formulation is complex, changing parameters and uncertainties are also to be tackled. This package was developed using GENEX and is being enhanced by SAIL.

Expert system for selection of pumps for irrigation

Banks in India provide loans to farmers at concessional rates for purchase of pumps. The sizing of the pump depends on the crop, the size of the farm, interval and duration of irrigation, static head of the well, type of pipe, etc. Further, the crop will vary with season and rotation of crop may take place once in two or three years. The pump that is selected should be capable of providing sufficient irrigation for worst case condition such as the crop that needs maximum irrigation,

static head of the well during summer, etc.

For the pump selection, a software package is required which would easily and quickly work out for all possible combinations and arrive at the correct capacity of the pump required. This package can be used to advise farmers and also by banks to quickly verify that the farmer is buying the pump of correct capacity.

The use of expert system approach for the development of the software package eliminates the need for a computer programmer, shortening of the development time by an order of magnitude, easy and quick updating of knowledge base, explanation facility, etc.

This package is developed using GENEX (General Purpose Expert System Shell) from CIRA, ER & DC. It also demonstrates the capabilities of GENEX to handle knowledge in the form of rules, mathematical relationships, and procedural knowledge, and other user-friendly features.

6. CONCLUSIONS AND RECOMMENDATIONS

The workshop generally agreed that of the various applications, diagnostic expert systems were now well establish tools for industry and other economic sectors. For developing countries they offered special advantages in the form of easy knowledge transfer, a way to remedy competitive disadvantages, e.g. compensation for the lack of experts and expertise in many areas. They were particularly effective for generic domains such as medical diagnosis, eye care, electronic diagnosis, mechanical diagnosis, weather forecasting and others.

On the other hand, there was much less experience with problems concerning broader topics that involve cultural factors, regulations and large complex organizations such as companies and governments. So far this had meant far fewer applications for problems such as production planning, financial planning, strategic planning, law, taxation and others. These were also areas where it was difficult to transport knowledge from country to country.

In these types of applications, developing countries were at a disadvantage in acquiring the knowledge, including their lack of experts, knowledge engineers and experience with modern management technologies. Partly this is reflected in the fact that although expert systems were able to provide abstract reasoning and explanations, in their rule-based form (the most used to date) they were brittle, i.e. unable to cope with unexpected situations, and their performance tended to degrade with time. There was a need to bring multiple paradigms together to solve the more complex problems, several participants felt.

One question was whether some areas were too complex to be modeled, their expertise to difficult to codify. Compared to diagnostic systems there was more uncertainty, more choice of ideas. The meeting agreed nevertheless that many of the prototypes presented had shown that such problems could be meaningfully tackled.

Greater assistance was required from methods of automatic knowledge generation such as machine learning and neural networks. Neural networks had the advantage of gradualism (learning ability), robustness (toward information noise) and generalizability (to cope with unexpected situations). Their known disadvantages included some knowledge remaining hidden (distributed among the neurons), and lack of an explanations capability. This lead to the idea of a connectionist decision support system (DSS) that could combine neural networks with conventional expert systems, thereby combining the ability to provide abstract reasoning and explanations with robustness.

Following discussion of a number of propositions presented by the UNIDO Secretariat, the workshop agreed to the following conclusions and recommendations.

Conclusions

1. The meeting agreed that no country, whether developed or developing could afford to be a silent spectator to the developments in artificial intelligence, particularly those concerned with expert systems. AI and ES were going to be key technologies for industry and business, opening new windows of opportunities for developing countries which would allow them to improve their competitive position and expand their market share. While full AI research would be prohibitively expensive for any single developing country, research efforts in the past decade had yielded a large number of tools and techniques that were now commercially available. Developing countries should be willing not only to adopt such tools for industrial applications but also to develop their own tools and systems where they were cost effective. Their primary emphasis, however, should be on developing new ES applications. The meeting emphasized that expert systems were both transferable technologies themselves as well as a powerful means of transferring other technologies between countries. In this context, advantage should be taken of the core excellence evident in some developing countries. Expert systems were also useful as tools to support and assist training programmes relevant to industry.

2. Expert systems in India were being developed in the context of a broad programme on knowledge-based computer systems that included speech recognition, pattern recognition, parallel processing, natural language processing,. AI in education and technology transfer. Each nodal centre had assigned objectives and a time frame of five years. Responding to an urgent need to help industry and government in the application of AI technology and tools, India had established a National Centre for Expert Systems as a technology transfer centre to transfer ideas and skills to people in industry and government. Its work covered education and training, joint projects, consultancy and development of application systems The centre worked in close collaboration with leading industrial organizations in selection and implementation of AI and ES tools and systems. The meeting felt that this multifaceted approach to ES systems development and their application in industry held a number of lessons for other developing countries, which could profit by adopting several of its approaches.

3. It was agreed that diagnostic systems of a technical nature were well established and their development and application by industry did not pose major problems in the participating countries. It was considered important, however, to concentrate also on developing expert systems that provided a basis for supporting decision making at the strategy and policy level both for governments, enterprises and international agencies. The strategic management of industrial development process is a complex issue involving a wide range of parameters, all of which may not have exact values. The meeting emphasized the need to develop further systems to cope with these problems. This need is accentuated by the fact that very often the right (domain) expertise to deal with some of these strategic management problems may not be readily available in some developing countries at the right time.

4. The prototype demonstrations and discussions gave a clear indication of the feasibility of developing expert systems as decision support mechanisms. Example of such prototypes included those on privatization strategy, international joint ventures, environmental impact assessment, industrial sickness, various aspects of competitiveness, etc.

5. Given the importance of ascertaining the competitive position of industry in the national and international settings, the workshop agreed that a prototype presented by the Monterrey Institute of Technology had good potential for application in developing countries. The idea was considered interesting and useful and could have wider applicability. It was agreed to develop the system further through the cooperation between India and Mexico as far as possible under the sponsorship of UNIDO. It was also agreed to work on the further development of the system on privatization and international joint ventures.

6. The meeting felt that the workshop itself had enabled the sharing of experience in the development of expert systems and their applications in industry in developing countries and that a mechanism enabling such exchange of views and developments by institutions and companies on a more regular basis would further promote expert systems in those countries.

Recommendations

1. Bearing in mind the potential contributions of expert systems in overcoming the lack of experts in many developing countries, their Governments should give priority to their promotion and support through nationally coordinated programmes for transferring skills and developing expert systems for industrial and other applications. Where appropriate, national centres for expert systems may be established to work with universities, institutions and the private sector. Subject to availability of resources, UNIDO is recommended to promote and support these activities.

2. Recognizing the importance of competitiveness as a sound basis for industrial development and strategic management, the workshop recommended the further development of the system presented by the Monterrey Institute of Technology through collaboration between the Mexican institute, NCES and UNIDO, with later participation by other interested countries.

3. In the same vein, UNIDO should, subject to availability of resources, follow up the development of decision support systems in other areas of strategic management; in particular, systems in the areas of privatization strategies, joint ventures, and environmental management techniques were recommended for further development.

4. The developers of all the prototypes and new shells presented at the workshop should continue their work and through UNIDO advise the other participants of their progress towards full-fledged operable systems.

5. To improve communications with and among institutions and companies involved in expert systems in developing countries, UNIDO should continue to monitor and disseminate information in this field. UNIDO should also explore the possibilities of establishing appropriate mechanisms such as a network of expert systems developers and users in those countries. This mechanism would also provide for a monitoring and reporting forum on the progress made in the development and industrial applications of expert systems meeting at regular intervals in different countries.

Annex 1

Work Programme

23 November

0900	-	1000	Inauguration
1000	-	1030	Coffee Break
			UNIDO Formalities : Mr. B O Karlsson
1030	-	1115	India's capabilities in AI and ES Prof. E Balagurusamy
1115	-	1215	Privatisation System
1215	-	1315	Environmental Impact Assessment
1315	-	1430	Lunch
1430	-	1530	Industrial Sickness Prediction
1530	-	1545	Tea Break
1545	-	1645	Business/Economic Forecasting
1645	-	1800	Hands on Session

24 November

0900	-	1015	Joint Ventures System
1015	-	1030	Coffee Break
1030	-	1115	Presentation of Prototype by IIT, Madras
1115	-	1300	Presentation and Discussion of Country Papers and Prototypes 1. Prof. Lin Yaouri, China 2. Prof. Sung Joo Park, Korea
1300	-	1430	Lunch
1430	-	1515	3. Prof. R Sadananda, Thailand
1515	-	1600	Discussion on applicability of Prototypes presented
1600	-	1615	Tea Break
1615	-	1730	Discussions (Continued)

25 November

0900	-	0930	Potential areas of application of Expert Systems in Developing Countries Prof. Kaushik Basu
0930	-	1030	Theorotical Framework of the Mexican Competitiveness Strategies System Prof. Kaushik Basu
1030	-	1100	Coffee Break
1100	-	1200	Competitiveness Strategies System Prof. C Scheel
1200	-	1300	Demonstration and Hands on Experience on Competitiveness Strategies System
1300	-	1430	Lunch
1430	-	1600	Discussion on Further Action on the Mexican Prototype and Future Plans
1600	-	1615	Tea Break
1615	-	1700	Discussions Continued
1900	-	2200	Reception & Dinner (Hosted by BLUE)

26 November

0900	-	1000	Presentation of Shells by NIIT
1000	-	1100	Presentation of Shells by TCS
1100	-	1130	Coffee Break
1130	-	1230	Presentation of Prototypes by ERDC
1230	-	1300	Presentation of Shells by BLUE
1300	-	1430	Lunch
1430	-	1730	Technical Visits Vendor Demonstrations
1900	-	2200	Discussions & Dinner (Hosted by NCES)

27 November

0900	-	1100	Presentation & Discussion of Draft Report
1100	-	1130	Coffee Break
1130	-	1230	Finalise Agenda for further development of Prototypes
1230	-	1400	Lunch
1400	-	1530	Adoption of Final Report with Conclusions and Recommendations
1530	-	1600	Tea Break
1600	-	1700	Concluding Sessions : NCES

Annex 2

List of Papers

1. Privatisation Expert System
   Blue Information Technology Ltd., New Delhi

2. Industrial Environmental Impact Evaluation Expert System
   Blue Information Technology Ltd., New Delhi

3. Knowledge Based System for Industry Sickness Prediction
   Prof. E Balagurusamy
   Mr. M S Sarma
   National Centre for Expert System, Hyderabad

4. Corporate Joint Ventures Expert System
   Blue Information Technology Ltd., New Delhi

5. IITM-DESS: Diagnostic Expert System Shell
   Indian Institute of Technology, Madras

6. IITMRULE: A Rule based Expert System Development Shell
   Indian Institute of Technology, Madras

7. XCUTE: Expert System for Selection Cutting Tools
   Indian Institute of Technology, Madras

8. A Diagnostic Expert System Shell (DESS-TH)
   and its Applications for Mechanical-Electric Devices
   Prof. Lin Yaouri
   Tsinghua University, China

9. Stratplanner: A Connectionist Expert System for
   Strategic Planning
   Prof. Sung Joo Park
   Korea Advanced Institute of Science & Technology
   South Korea

10. The Intelligent Distributed Information System for
    Competitiveness Strategies (INTELLICOM)
    Dr. Carlos Scheel
    Instituto Technologico de Monterrey, Mexico

11. Expert System for Allocation and Scheduling of
    Transportation of Coal
    Dr. B Narayanan Nair
    Electronic Research and Development Centre,
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12. Expert System for Selection of Pumps for Irrigation
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Annex 3

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