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EXPERT SYSTEMS IN PRODUCTION: AN EXPLORATORY STUDY

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ABSTRACT

The paper concerns itself with the applications of a branch of artificial intelligence called "expert systems". It describes some of expert systems' industrial engineering applications according to category, model or prototype name, developer, problem domain, decision output, development tools, and methodology or assessment. The study focuses on the wide-ranging applications of expert systems in production especially in the areas of materials handling, process specification and planning, production planning and scheduling, simulation and data analysis, operations analysis, facility and workplace design, database management, equipment diagnosis, robotic, and quality assurance. A survey of 100 expert systems production applications reveals its main uses as follows: planning (23%), diagnosis (17%), design (14%), and control (14%). The paper finally ends with the prospects and projection of research and development on expert systems in the field of industrial engineering in the Philippines.

INTRODUCTION

Artificial Intelligence involves the transfer of intelligence to machines. When AI attempts to simulate the decision-making processes of the human expert's mind, the particular field is called *expert systems*. More technically, expert systems (ES) is a form of artificial intelligence which embodies in the computer software knowledge and inference procedures to solve problems normally requiring human expertise [1].

Expert Systems software basically deals with the processing of expertise, in contrast to conventional programming which involves the procedural manipulation of data and facts. Using special-purpose programming languages or ES shells, knowledge and heuristics are coded into the

knowledge base of the system (equivalent to database in traditional computer systems). The knowledge base is then manipulated by a separate control strategy called the ***inference engine*** which draws the inferences and provides explanations based on information from the knowledge base [2].

Traditionally, the development and implementation of expert systems had been done using mainframe and minicomputers due to its huge memory, fast processing, and large storage requirements. Nowadays, with modern developments in both hardware and software, microcomputer-based application is exhibiting a positive pattern of growth.

Regardless of the hardware requirement of expert systems, certain prerequisites need to be satisfied in order to maximize the technology's benefits and avoid its pitfalls [3]. They are as follows:

the domain of application is narrow;
there are few experts in the domain;
the experts can perform significantly better than amateurs;
the expertise can be stated in a form that permits knowledge to be represented and inferences to be drawn;
the expertise can be formulated on an incremental basis;
there is argument among the specialists about the knowledge;
there is a need to disseminate the expertise for cost or performance reasons;
adequate time and resources can be committed; and
the potential benefits are high.

INDUSTRIAL ENGINEERING APPLICATIONS OF EXPERT SYSTEMS

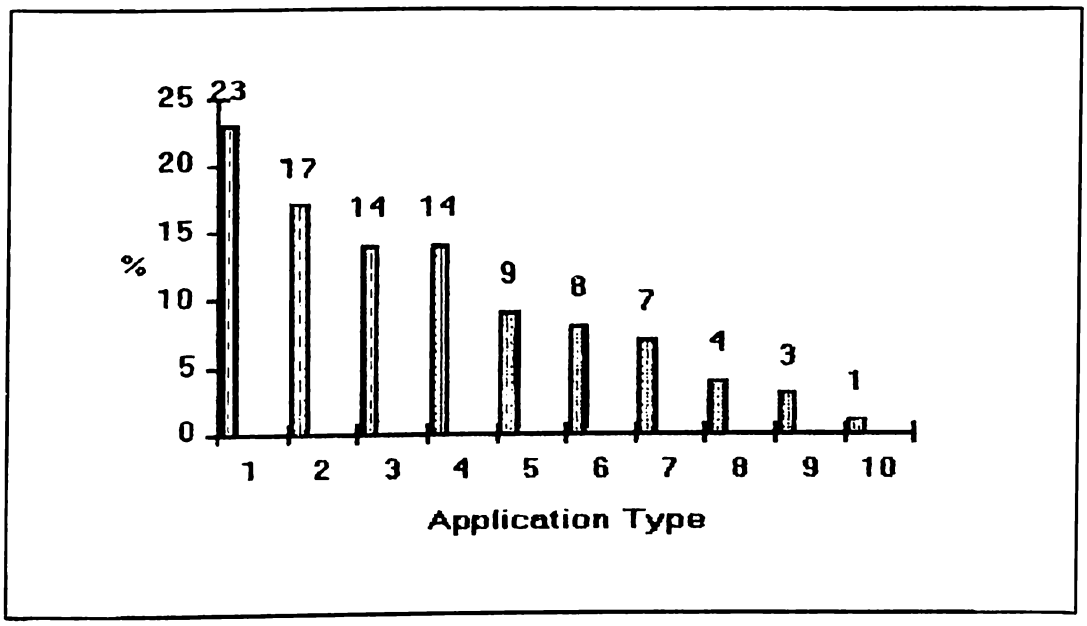
So far, industrial engineering applications of expert systems have been successfully utilized in Australia, Japan, United Kingdom, United States, and other advanced countries. Applications of expert systems in industrial engineering have not only increased the productivity of experts but have improved the efficiency of systems as well. Production planning applications, which involve the analysis and construction of schedules, have brought about reduced processing time and more consistent transaction processing. In the area of materials handling, control and monitoring of automated material handling systems had been able to increase production rates in manufacturing plants. To heed the call for world-class goods and services, expert systems on quality have also been utilized in the production floor.

To date, different industrial engineering application areas of expert systems have been recorded. These are on the areas of *scheduling, materials handling, process specification and planning, production planning and scheduling, simulation and data analysis, operations analysis, facility and workplace design, information systems, equipment diagnosis, robotic, and quality assurance.*

Since the inception of expert systems in the early 1980's, numerous applications have been developed in various disciplines. Bayer et al. [4] classifies ten applications of expertise, as follows,

Interpretation:	analysis of data to determine their meaning;
Diagnosis:	determination of a disease based on the interpretation of data;
Monitoring:	continuous interpretation of signals;
Prediction:	inferring probable consequences of given situations;
Planning:	design of actions;
Design:	configuration of objects under constraints;
Debugging:	prescription of remedies for malfunctions;
Repair:	execution of a plan to administer a prescribed remedy;
Instruction:	diagnosis, debugging, and repair of student behavior; and
Control:	interpretation, prediction, repair, and monitoring of system behaviors.

To categorize expert systems technology by application type, a survey was conducted on 100 industrial engineering-related expert systems designed or developed mainly for production. The survey revealed the percentage distribution of the technology by application type, shown in Figure 1.



LEGEND:

1	Planning	6	Interpretation
2	Diagnosis	7	Prediction
3	Design	8	Instruction
4	Control	9	Debugging
5	Repair	10	Monitoring

Figure 1
Percentage Distribution of Industrial Engineering Applications of Expert Systems

PRODUCTION APPLICATIONS OF EXPERT SYSTEMS

Among the 100 expert systems surveyed, a sample listing of production-related applications are tabulated in Table 1 according to application type, model or prototype name, developer, problem domain, decision output, development tool, and status or assessment.

Table 1.
Production Applications of Expert Systems

Production Applications	Expert Systems Model/ Prototype	Developer	Problem Domain	Output	Computer System and/or Programming Language	Status and/or Assessment
1. ASSEMBLY LINE ANALYSIS	Bicycle Assembly Line Advisor [5] (BALA)	Khek Cuon Yong	Determination of value-added measure for design of bicycle, knowledge transfer	Aid for design engineer in economic analysis of operations; Instruction of new operators about bicycle assembly procedures	VP-Expert shell	
2. EQUIPMENT DIAGNOSIS	COOKER [6]	Texas Instruments and Campbell Soup Company	Detection and repair advice on equipment	Trouble-shooting and maintenance tips in soup manufacturing	Micro-computer/ Personal Consultant shell	One of the most widely-known commercial expert systems
		Texas Instruments	Diagnosis of equipment malfunction	Trouble-shooting tips in semiconductor manufacturing	Micro-computer/ Personal Consultant shell	Production Usage
3. FACILITY AND WORK-PLACE DESIGN	FAcility Design Expert System [7] (FADES)	Purdue University	Design and planning of facilities	Advice on system selection, equipment justification, conflict identification, and layout	VAX/ PROLOG	Addresses general facility design problems with focus on programmable manufacturing operations
	Sitting Workplace Analysis and Design [1] (SWAD)	University of Miami	Design and analysis of workplace using principles of motion economy and workplace simplification	Workplace design and calculations	Micro-computer/ Advanced BASIC	Presents an initial step in facilitating design and analysis off sitting workplaces
4. INFORMATION SYSTEMS	Image Database Management [3] (IDBM)		Manipulation and management of pictorial information in database systems	Database management system to store images, pictures, and graphs	Micro-computer/ C	Refinement to allow storage and retrieval of numeric and textual information, and to allow operations with software packages
5. MATERIALS HANDLING	MAterials Handling DEsign [8] (MAHDE)	University of Virginia and General Electric	Examination of meterial handling system design problem as related to facility design	Configuration of materials handling equipment within a facility		More restricted in scope than FADES

Production Applications	Expert Systems Model/ Prototype	Developer	Problem Domain	Output	Computer System and/or Programming Language	Status and/or Assessment
6. OPERATION ANALYSIS	FALCON [9]	University of Delaware	Identification of probable causes of disturbances in chemical process plants	List of probable causes of disturbances	LISP	Interprets data consisting of numerical values from gauges and status of alarms and switches
7. PROCESS PLANNING	GARI [5]	Descotte and Latombe	Determination of machining process plans	Plans for the sequencing of machining cuts of mechanical parts	MACLISP	Domain is restricted to the metal cutting industry
	Technostructure of Machining [5] (TOM)	University of Tokyo and IPK/IWF Berlin	Planning of machining process	Process plan for for the machining of mechanical parts	VAX/ PASCAL	
	CABle PROcessor (CABPRO) [8]	Allied-Signal, Inc.	Reduce manpower effort in process planning	Work directions used to fabricate multiwire c[illegible]es	Networked workstations/ HERB shell (prototype); C and LISP (production)	Significant time savings; Continuing effort to improve user interface
8. PRODUCTION PLANNING AND SCHEDULING	Interactive Critical Path Analysis [3] (ICPA)	Brighton Polytechnic, United Kingdom	Project network construction and analysis	Network representation and critical path calculations	Micro-computer/ BASIC	Easy, friendly, and no computing skills needed for operation; lacks resource-handling activity unless modification of databases is done
	Intelligent Scheduling and Information System [5] (ISIS)	Carnegie-Mellon University	Formulation of a job shop schedule	Job shop schedule	SRL; LISP	Highly rated by expert schedulers in a factory environment
	Production Scheduling Advisor [6]	Stone & Webster	General planning when production requirements cannot be met based on data	Decisions on which constraints to eliminate in order to meet demand	Micro-computer/ Information Builders Level 5	Combines expert system with graphics, spreadsheet, and linear programming
9. QUALITY MANAGE-MENT AND CONTROL	Ritz Line Expert System [6]	RJR Nabisco	Quality assurance advisor for supervisors and operators	Advice on how and where to correct the problem in production line	Lisp machine (prototype); micro-computer (production)	Successful project; positive user response to system
		University of Cincinnati and Northern Kentucky University [10]	Interpretation of statistical quality control charts, diagnosis of assignable causes, and determination of corrective action	Advice and recommendation salong with relative confidence factors	Micro-computer/ EXSYS shell	The need for further study on pattern recognition
10. REAL-TIME CONTROL SYSTEM	Hybrid EXpert System CONtroller (HEXSCON) [3]	SRI International	System control	Tracking and warning signals and corresponding counter-measures	Micro-computer/ PASCAL	Wide range of problem domain; variations in memory capacity, hardware, response time factors to suit function
	Chemical Process Control Expert System [3]	Nelsons Acetate Ltd.	Application and interpretation of techniques and processes for ensuring the quality of process	Automatic interface to plant instrumentation and a simplified user interface for plant operators	KES shell	Consists of primary and secondary rules in five knowledge bases

Production Applications	Expert Systems Model/ Prototype	Developer	Problem Domain	Output	Computer System and/or Programming Language	Status and/or Assessment
11. ROBOTICS	ROBot EXpert (ROBEX) [5]	Sunku and Badiru	Planning and implementation of robots	Advice to manufacturing engineers on robot system implementation	VP-Expert shell	Found to teach engineers about robot capability; future enhancements being considered
12. SIMULATION AND DATA ANALYSIS	Intelligent SIMulator (ISIM) [6]	AI Technologies, Inc.	Simulation tool for process engineers, designers, and control engineers	Allows any user unfamiliar with simulation technology and modeling to generate knowledge bases and understand simulation	Mercury KBE object-oriented programming	Varied range of applications

Sources: Compiled from various sources

The study showed some pertinent findings regarding expert systems applications in production:

applications are relatively non-procedural and domain-specific;
research pioneered by academe and sustained through linkage with the private sector;
availability of applications in microcomputers with hardware enhancements in processing speed and memory allocation;
programming flexibility with the availability of implementation languages (e.g. Pascal and C) in addition to expert systems languages and shells;
and provision of interfaces with other software systems (e.g. database, computer-aided manufacturing).

RESEARCH AND DEVELOPMENT OPPORTUNITIES IN PRODUCTION

Opportunities for improvement in productivity, quality, and efficiency abound in Philippine industries. Technical know-how and expertise on these improvement areas, however, need to be made more readily accessible, comprehensible, and affordable to the all sectors of manufacturing and all members of the production organization.

With the capability of expert systems technology to replicate human expertise, industrial engineering tools, techniques, concepts, and expertise could be made available to management, supervisors, operators, and technicians as decision support systems. Possible areas of expert systems development in production are enumerated below.

Work Measurement: motion and time measurement, time standards analysis, computation, and interpretation
Systems and procedures: productivity analysis
Manufacturing processes: processes selection, technology transfer, hardware configuration

Industrial Organization and Management:	operations management tutorial; data interpretation, training, personnel training, quality measurement and improvement
Operations Research:	modeling and interpretation
Systems Simulation:	modeling and interpretation
Information Systems:	tutorial and design

Badiru [*] recommends other potential applications in industrial engineering: *computer-aided manufacturing, computer-aided design, computer-aided education, flexible manufacturing, human resources management, office automation, technical diagnosis and maintenance, logistics, reliability, safety, project management, and statistics and data analysis.*

CONCLUSION

The technology of expert systems has been delivering beneficial results for users worldwide. Rightful credit goes to universities who have pioneered research in AI and ES and, consequently, to the manufacturing companies who through their Research & Development arms capitalized on such a technology.

With the successes that the technology has reaped in various disciplines, the manufacturing sector in the Philippines could tap the technology to disseminate technical expertise among the sectors of industry, academe, and government. Presently, the academe has been looking into its relevant application areas. With the availability of the necessary hardware, software, and the appropriate expertise, ES technology could address a wealth of problems confronting Philippine manufacturing sector. Improvements in productivity and quality could be realized provided that the development and implementation of expert systems is justified in the long run.

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