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CONTENIDO

Artículos

Análisis y Comentarios

Notas Técnicas

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EXPERT SYSTEMS FOR MANUFACTURING

Juan Carlos Chaves de Oña

RESUMEN

El objetivo de este artículo es describir sistemas expertos en el campo de la manufactura Se discuten brevemente las características de esta tecnología, las barreras para el desarrollo y los factores necesarios para el éxito. Se explican las razones por las que la tecnología no se ha difundido más, los tipos de sistemas existentes, y las tendencias a futuro.

SUMMARY

The objective of this paper is to summarize the status of expert systems in manufacturing. The characteristics of this technology are discussed, as well as barriers to development and critical factors for success. Reasons are given to explain why the technology is not as widespread as expected, the types of systems are described, and future trends are given.

INTRODUCTION

The purpose of this work is to provide insight of the status of expert system technology in manufacturing. One of the biggest concerns of researchers should be that the results of the studies can actually be put into practice , in this case, in a manufacturing environment. This is the real test . With this in mind, this work investigates how widespread is the use of these systems, the type of systems available, state of the art systems , and trends for the future.

General background of expert systems is provided, as well as references to expand on what is presented here.

This paper also mentions guidelines for development of expert systems in manufacturing environments, and describe areas which are better suited for applications. A list of a sample applications is given, and references to other sources are provided for further research .

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Finally, systems that constitute the state of the art are discussed in greater detail than the previous applications, in order to understand the trends of the expert system technology.

Expert systems are becoming more prevalent in industry, but they are still not in widespread use. Surveys performed indicate that manufacturers are among the largest group of expert system developers. However, other statistics affirm that only 4% of surveyed manufacturers use Artificial Intelligence (AI) in their operations (14). This means that there is still a great potential for development. Reasons for slower development than expected are important to consider, and are mentioned in this work.

BACKGROUND OF EXCPERT SYSTEMS

Expert Systems are computer applications that attempt to emulate the thinking of a human expert during decision making. As Waterman describes them, they are computer programs that use expert knowledge to attain high levels of knowledge in a narrow/specific problem area. The expert system consists of a working area of memory for computation or inference, an inference engine, and one or more knowledge bases with a user interface. Simply stated an expert system is a computer program that assists in doing a particular task, it distributes knowledge to make it accessible for non-experts in the subject. The functions performed by these systems are: to preserve, analyze ,and combine knowledge, and are particularly well suited for teaching (16). The expert system in essence, attempts to emulate the human brain.

The knowledge base:

The brain contains enormous collection of information/knowledge, surface knowledge, and knowledge about our knowledge, deep knowledge. Bits of information are important, but relationships are the key in expert systems. These relationships may be stored in the form of rules (heuristics), of the form: IF..THEN. The rule should have a rule label for tracking purposes, given the possibility of a large number of rules.

An example of a rule is the following:

label	Taking Umbrella
condition	If (it is raining)
action	Then (take an umbrella)
explanation	Because it will stop you from getting wet.

The intelligence of an expert system depends on the way which the inference engine links the rules together.

There are four ways of representing knowledge: production rules, structured production rules (categorized production rules), frames and logic. For a detailed discussion of these, see Andrew Kusiak, Intelligent Manufacturing, Systems (7). Production rules are easier to implement and widespread use in industry and are the subject of this discussion.

There are two ways in which the inference engine links rules together: forward and backward chaining. Forward chaining involves asking questions. The answers to these questions are added to the working memory, and the rules are run again using these answers. This data driven method is suitable when the number of outcomes is large (3).

The backward chaining (goal driven) strategy: involves identifying conclusions and tracking back to see where they came from. If the outcomes are known, and not many, this technique is efficient. Other important aspect to consider is the depth versus breadth issue. The previous paragraphs discussed the first dimension of a search, which is, forward or backward chaining. Depth versus breadth is the second dimension. At times, resources and time may require different search strategy. Most systems include depth search first, followed by breadth search. A few may provide a choice (3).

The following paragraph illustrates how a user would interrogate an expert system. Most actual expert systems are designed to be user friendly in order to facilitate implementation. A menu system is likely to give choices to the user in order to access available applications. After choosing the application, the user may be prompted to state the objective so that the inference engine will use the part of the knowledge base that applies to the problem. Some systems have a choice of depth versus breadth search choice. Subsequently, the system asks a series of questions taken from the rules. Each question changes the knowledge temporarily and causes other questions to be triggered. There is no set algorithm for solution . The questions asked by the system are triggered by previous answers to other rules. Depending on the system, there are various help levels. Finally the system iterates until a conclusion is reached. The user may be prompted to change answers to see other outcomes, or restart, or perhaps switch and start in a new knowledge base (3).

The use of expert systems in manufacturing has been increasing since their introduction more than twenty years ago. Manufacturing processes are getting more complex, requiring more sophisticated monitoring and control equipment. Real time expert systems release stress and overload of individuals on the modern manufacturing environments (14). In the 80's, expert systems were being sold as a panacea to solve all problems (12). Prices soared, but results have not met the expectations. There is still a mistrust. The image problem is still an issue that constitutes an obstacle for new applications.

OBSTACLES TO EXPERT SYSTEM DEVELOPMENT

Software and Hardware development have been running faster than the actual users can cope with. This is, the technology tends to drive the applications. Then, expert systems, do not result as a solution to a particular problem (3). Other important factors to consider: Development time is very short compared to the period of usage of the system. Knowledge updating will be required constantly. This is done easier than in other systems. These systems use an expert or group of experts to create a set of rules. The problem is that experts are unlikely to agree in the solution of different issues. The system assumes that there is a best solution approach for a problem. At times some problems are unanswerable, and the system should not give any answer at all. In business, due to limited resources, many decisions are "satisficed" rather than "optimised " (3).

AREAS BEST SUITED FOR EXPERT SYSTEM APPLICATION

Expert systems are good to solve well bounded, well understood problems, but are limited in case of rule systems to the quality of the set of rules used. Some arguments in favor of expert systems are: These systems store, assimilate and retrieve knowledge in order to give advice. The new systems are more transparent to the user, versatile, and better suited for training They can be started in a small part of a particular domain and expanded, so the knowledge base can grow. The set of rules for example can always be changed. Expert systems differ from traditional programming methods since expert system programs need not to be rewritten. The representation of knowledge in expert systems has brought a dramatic change from previous computing technology.

Implementation of expert systems promises time and cost savings if the scope of the project is well defined from the start.

NECESSARY FACTORS FOR SUCCESS OF EXPERT SYSTEM IMPLEMENTATION

Some general guidelines are important for success of expert system implementation. The focus must be on a small well defined problem that has significant historical information. The problem must be clearly defined. Also, it should be broken into smaller parts. Next, the experts on the subject need to be identified. One must always make sure that the application drives the technology, and that the available data is not in a process of change. It is extremely important to obtain enthusiastic support for implementation in order to be able to pursue the project beyond the prototype stage.

BARRIERS THAT BUSINESSES SHOULD OVERCOME

It is difficult to collect universal reliable knowledge since it depends on circumstance and experience of the experts.

The knowledge must be updated regularly, thus making a self learning feature very desirable (13).

A complete treatment of the proper implementation considerations for expert systems is included in A Methodology for Determining Proper Institutionalization of An expert System within an Organization, by Jay Liebowitz . Also, Managing Industrial Expert System Development by William J. Kaminsky gives guidelines for implementation (11).

Management must be able and willing to invest in systems and people in order to change the culture, in order to encourage the use of tools such as expert systems (12).

EXPERT SYSTEMS FOR MANUFACTURING

The purpose of this section is to enable the reader to be familiar with available expert system applications. This is a small list to give an idea of the nature of the applications of this technology in manufacturing systems.

In Object Oriented Expert System Architectures manufacturing Quality Management "A proactive role for expert systems in quality control", Shawn Bird provides a small survey of systems which is included below (2). Other systems are also listed which resulted from further research. Systems may be categorized in the following manner: for debugging, control, design, diagnosis, interpretation (inferring system malfunctions from observed variables), instruction, monitoring, planning, prediction , and repair.

The control category includes interpretation, prediction, repair, and monitoring. Few expert systems integrate these last four. An example is ECESIS.

-ECESIS by Boeing Aerospace Company; is a system to control the environmental control /life support subsystem of a manned space station.

Systems developed for design are listed below:

-DESPLATE diagnoses steel plates for abnormal shape and then attempts to find the causes and suggest the remedies.

-ASASP assists quality engineers to design a sampling plan

-ROSCAT Developed for component design and specification of ISO tolerances in rotational component manufacture.

-EXCAST combines design and prediction in design of axisymmetrical casting components and in predicting metal casting defects .

-TRANSISTOR SIZING SYSTEM is used to aid integrated circuit designers in determining the physical size of circuit transistors by analyzing speed and power consumption goals.

The reader may investigate other Expert systems that perform intelligent factory planning and scheduling. Some available are: MADEMA, OPIS, IMACS, PTRANS, AND ISIS.

Diagnostic and monitoring expert systems:

-FALCON identifies process disturbances in a chemical plant.

-FAITH was developed by Jet Propulsion Laboratories as a diagnostic system to identify aircraft malfunction

-PDS is a process oriented expert system that gathers information from sensors and determines manufacturing process deviations and malfunctions.

A listing of over 150 expert systems designed to perform CAPP (computer- aided process planning) has been done by Alting and Zhang (1)

A survey of close to 90 expert systems for diagnostics and maintenance is found in V.D. Majstorovic (15). For additional information of the mentioned systems refer to Bird (2).

In addition to the systems described above, the search of literature revealed the following industrial applications of interest:

-DIAESS is a diagnosis expert system shell developed to assist in the generation of expert systems for fault diagnosis of printed board assemblies. It is based on ENTRAN, a shell developed at the University of Edinburgh in cooperation with Alcatel (3). The system uses an algorithm to generate rules that represent the knowledge (4).

-SONIA is a job shop scheduling system which helps plan and control short-term manufacturing activities, while a generative process planning system was developed as part of the Eureka project of Alcatel with the aim of using design data to plan the manufacturing processes (4). The process planning system is described in the section of trends in this paper. Scheduling constraints are the release dates, operation duration and precedence, resource capability and availability, and resource sharing. Also, due dates, frequency of tool changes, and inventory are considered. SONIA performs the following functions: selection and capacity planning, resource allocation, detailed scheduling, real-time control of disturbances and replanning, and plan failure test using simulation. The system integrates both predictive and reactive knowledge sources. The system takes the output from an MRP2 system and manages the manufacturing system in real time (4).

An Expert Scheduling System for Material Handling Hoists is presented. Decision rules are used, and simulation experiments involving changes in workloads and causing breakdowns are performed to refine the rules. The goal is to schedule hoist movements such that throughput is maximized while following production programs (8).

AT & T and Inference Corp. has developed an expert system called the Expert Capacity &

Material System XCAM. This system makes production plan evaluation seventeen times faster (12) than by other means. Critical material support issues associated with schedule changes are addressed by rules of the material analysis. It insures that material supply is in line, and reduces examination of 10000 parts to 100. Productivity is up by 100 times. The code for a product is entered, as well as the ship date, and the expert system will query the MRP database and VSAM files, which contain the bill of materials, structure, inventory, customer order information, forecast and capacity to determine availability of materials requested, how the product will fit the manufacturing schedule, and whether the ship date can be met (12).

General Dynamics, Intellection, and Automation and Robotics Research Institute (University of Texas/Arlington) have developed an expert scheduling system to be used in the manufacture of the F-16. The key in this production operation is to avoid excess work in progress at the final mating line as well as mismatch of parts. The system is able to backward schedule from the due date and forward schedule from the first operation to when a part will arrive. If a part is too early or too late the system simulates iterations of the schedule to perform the required adjustment. Intellection customized their existing production planning and scheduling software. Linkage with and MRP- system is on the making (12).

Ford Motor Company has developed an expert system for the simultaneous engineering of electronic products. Data on plant constraints, relationships between products and plants, cost analyses, process planning information, and design rule checking are stored in the system. This information is integrated with CAD/CAM and CAE systems used by the product designers. One part of this system , the Manufacturability Design Rule Checker (MDRC), is an Expert System that integrates the design and manufacture of printed wiring boards (PWB's). The system consists of a MDRC engine/graphic interface and a rule base with rules in textual form. There are five types of rules: attribute rules, component to component minimum distance rules, keep out rules, process order rules, and tooling rules. By integration of design and manufacture MDRC, reduces design time, decreases the need for plant feasibility checks, and allows designers to develop higher quality products (12).

TRENDS AND FUTURE

Knowledge processing is a complement of other data processing techniques. Expert systems utilize the knowledge processing capabilities to contribute heavily in the implementation of computer integrated manufacturing.

There is always a greater need for process planning efficiency and higher planning quality . A system for generative process planning was on the prototype stage at the date of publication. Computer aided process planning CAPP which is the interface between technological and administrative functions is becoming more important. Three methods of process planning exist: Adaptive planning takes an existing process plan for a similar part and adapts it to use with the new part. Variant Planning involves the generation of a new process plan from a standard plan. Generative Planning involves generating a new process plan that creates an optimum sequence of manufacturing operations using more sophisticated decision algorithms The system obtains its input from a 3D CAD model in addition to a large technology database (4). Because of the complexity of process planning, it is still one of the weakest points in the automation of the entire manufacturing process.

There are two main activities in the process planning: recognition of the shape of the part to be manufactured, and the generation of a plan defining how it can be manufactured. 3D cad data is translated into manufacturing features. Catalogue information, machine tables, cutting parameters etc. Are stored in a conventional database, and restrictions of usage of tools , machines and interdependencies are present in the form of rules.. A method of finding the best solution called constraint satisfaction mechanism is used.

A first prototype that covers a limited number of piece parts with pockets and slots of any size and any position. The system can explain decisions and answer questions from the user (4).

The Process Planning Expert System for cold forging is capable of planning processes for hollow and solid axisymmetric products. Work has been done in the areas of knowledge acquisition, geometric description, generation of processes, determination of order of evaluation, evaluation and visualization of process and verification of metal flow with Finite Element Method Simulation (FEM). Development is still at an early stage. The demand for process planning expert system will increase as computer simulation becomes more widely available in industry. For practical implementation the following is required: Establish a standard for knowledge acquisition, integrate the expert system with FEM simulation, including neural networks, fuzzy logic and other information processing techniques. Defect prediction, tooling design and cost accounting are features that should be included. Cold forging combines expert systems with neural networks. This process is normally performed at room temperature, and the main attraction is that products can be made near net shape. However, large strain, and fracture of tools occur, defect in product, or seizures between billet and tool occur easily. This process requires several intermediate operations (17).

Planning procedures for a forming process is not easy, partly because an insufficient knowledge base on the nature of cold forming. This system includes features such as product registration, process generation, priority determination ,process evaluation, and computer simulation. At the present, only rotational axisymmetric products are included. The process consists of a procedure to transform the partial design features of a product into a sequence of cold forging operations. Process generation is attempted with the variant approach first, that is will attempt to use processes used in the past. If there is no existing variant, it uses the generative approach and complete a new process. The authors propose a method of generating cold forged process of cold forged products via neural networks for pattern recognition of preforms.

There is a great potential in the hybrid neural networks/expert system tools. Combining pattern matching and classification capabilities of neural networks with rule based expert systems. In the past, the neural network experts attempted to separate the technology from other advanced techniques. The real potential is in the use in conjunction with expert systems. However, neural nets have a steep learning curve, a lack of standard development methodologies, demanding processing requirements, and integration issues. Nevertheless, neural network applications in conjunction with expert systems are a real possibility today (5)

LNK Corporation in Riverdale Maryland has combined expert system with induced learning from neural networks . For additional discussion on the subject refer to InFuse, An integrated expert neural network for Intelligent Sensor Fusion (10). The next paragraph gives an example in the manufacturing sector.

An Expert Self-Organizing Neural Network for the Design of Cellular Manufacturing Systems has been under study. A multilayer hybrid neural network simulates cellular manufacturing system design. The net is constraint bound and takes into account duplicate machine availability and machine capacity during the cell design process. An interactive expert system then takes the input from the neural network and uses alternate process plans to reassign any exceptional parts that result during the constrained initial cell design. The hybrid neural net-expert system gives flexibility, includes desired constraints and objectives (11).

The system is also based on the application of group technology to manufacturing systems design. It solves multiobjective, multiconstraint machine component grouping problems. The neural network can classify a given set of input patterns with little training or supervision. This is important when the solution for a classification problem is not known, thus prior training is not possible. The neural network has three layers of nodes, an input layer, a middle or hidden layer, and an output layer. The hidden layer nodes are used to accomplish object oriented clustering . Each middle layer node is representative of each machine type used in the cell design process. Nodes has feedforward and feedback connection (11). The output of the neural network is: The current loading of machines in different cells, machine cells and component families, exceptional parts that cannot be accommodated. The expert system evaluates the best process plan based on the above information and user input as alternate process plans, layout, and process times and setup times of alternate process plans. The forward chaining technique with production rules is used to evaluate the alternate process plans . In summary, the hybrid approach is capable of the following:

1- Clustering of components / machines into various groups of clusters,
2- Consider the number of machines of each type available to form mutually exclusive cells to carry out cellular manufacturing system design.
3- Consider actual capacities available on each of the machines.
4- Deal with exceptional components as a result of 1 and 2, by considering alternate process plans.
5- Consider material handling cost, processing cost, and setup cost during evaluation of alternate process plans (11).

Expert Systems are inherently weak to handle imprecision and linguistic terms. Fuzzy set theory provides a way to deal with linguistic terms also an imprecise numeric term can be expressed by a fuzzy number. The use of fuzzy set theory has caused evolution in expert systems. For a full description refer to Abraham Kandel, Fuzzy Expert Sytems (6).An example of this application is given in Fuzzy Application of Temporal Constraints in Active Expert Database Systems by Richard T. Bechtold (10). The new graphic user interfaces and window environment will foster more advanced systems as well as high MIPS computers. Connectivity within an entire enterprise data set will increase the potential of expert systems.

Some areas in which real time expert systems can contribute are sensor validation, alarm monitoring, plant and process diagnosis and supervisory control of optimization. The way forward for intelligent control is real time expert system control. Expert system based control and optimization involves closed loop control which is desirable. However, industry has resisted this and relegated expert systems to an advisory role (14).

Operational production management will have to be extended from a work cell level to a factory wide control system. Then, the overall system will be composed of a series of cells with their own scheduling system. Coordination with master production planning is required, a distributed software architecture is needed for the integration of expert knowledge of various disciplines at tactical and operational levels (4).

Siemens Corporate Research Laboratories is continuing the development of a Distributed Intelligent Manufacturing Scheduling System (10).

IBM has developed a project called MOM-(measurement of on-line manufacturing), which makes extensive use of expert systems. Control over manufacturing operations is provided by a real time monitoring and process checking for the manufacture of integrated circuit boards. A RISK 6000 network with G2 from Gensym Corp. (the expert system), and Gemstone from Servio Corp. as the database has been developed. A statistical process control product from Statware Inc. Is also included. G2 features telewindows, that enables engineers and process managers watch the application. A graphic model of the system was created. Icons represent test stations objects and process variables. Objects were placed on a workspace on the computer screen and connected them to show relationships. The result was a schematic diagram from where the rules for the system were derived. These rules provide G2 with the real-time reasoning engine (13). For an additional list of Expert Systems for Process Planning refer to Andrew Kusiak, in Intelligent Manufacturing Systems. At the present expert systems cannot create their own help based on the rules in the knowledge base. This would be a desirable feature in future systems (3).

CONCLUSION

The present work has provided introductory background in rule based expert systems. Obstacles for expert systems in general have been discussed as well as areas best suited for these systems and necessary factors for success in implementation

A sample of expert system applications is given with additional sources for the reader who has interest for further research on existing applications.

A few applications were chosen as representative of the trends/tendencies of expert system development, and were described in more detail.

Regardless of the fact that applications are abundant, the extent of usage of expert systems in manufacturing is not as high as it could be due to unmet expectations of the users in the 80's when these systems had a fast development. The main reason for this is that the technology led the applications rather than the opposite.

The direction of research points towards more complex real-time systems as shown by process planning applications. Expert Systems are bound to be used in conjunction with other technologies and concepts, as neural networks, and fuzzy logic. The combination of technologies will permit to capitalize on the strengths of each. For example, neural networks will assist expert systems in pattern recognition. These new technologies are bound to merge in order to enable the solution of highly complex problems in the manufacturing environment.

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