Expert Systems in Manufacturing

Matthew N. O. Sadiku, Kazeem B. Olanrewaju, and Sarhan M. Musa
Roy G. Perry College of Engineering
Prairie View A&M University

Abstract— Expect systems are a product of artificial intelligence, the branch of computer scienceconcerned with developing programs that exhibit intelligent behavior. An expert system is a computer program that uses the knowledge underlying human expertise to solve problems. Expert's knowledge is stored inside the program and users can call upon the computer for specific advice, help, diagnosis and rectification as needed. This paper provides an introduction to the applications of expert systems in manufacturing.

Index Terms— expert systems, manufacturing, artificial intelligence,computer program..

1 Introduction

An expert system, an artificial intelligence tool, is designed to capture the knowledge and skill of human experts in a specific domain and pass it on to future generations. The key idea behind expert system is that expertise, which is the vast body of task specific knowledge, can be transferred from human to computer. Expert systems are one of the most exciting and promising applications of computers. An expert system (ES) is designed to emulate the decision-making ability of a human expert. It encapsulates specialist knowledge of a particular domain of expertise and can make intelligent decisions [1].

Today, the manufacturing industry is experiencing major changes due to aggressive global competition, Increasing customer expectations, expanding choice of materials. To cope with increasing demands of today's dynamic and competitive market, manufacturing processes are automated. The integration of expert systems into mainstream information technology will promote increased exploitation of this technology in the manufacturing sector. The expert system is the heart of the manufacturing facility and is mainly used to manage situations that would normally require the worker's expertise [2].

2 Overview on Expert Systems

An expert system (also known as a knowledge-based system) is a computer system that emulates the decision-making ability of a human expert. It acts in all respects like a human expert, using human knowledge to solve problems that would require human intelligence. It is a typical example of a knowledge-based system.

An expert system (ES) is typically shown in Figure 1 [3]. The figure shows that an ES consists of three main components: (1) knowledge base, (2) problem-solving and inference engine, (3) human-machine interface. Thus, an ES is an intelligent computer program that accepts input through the user interface and uses knowledge in the knowledge base to make logical decisions through the inference mechanism. The knowledge base (long-term memory) is where the experts' knowledge is stored. The knowledge base consists of a set of IF…THEN rules, facts, and heuristics. We recall the popular saying: Knowledge is power. Problems cannot be solved without detailed knowledge of the problem and how it will be solved. It is the job of a knowledge engineer to incorporate expert knowledge in the ES by writing the necessary software. The inference engine draws logical conclusions (inferences) based on the information available in the knowledge base. It is the software that provides means of interpreting command and accessing the knowledge to solve a given problem.

An expert system without knowledge base is known as a shell. The inference engine is regarded as brain because it provides the ways for reasoning about information in the knowledge base. Inference can be performed using semantics networks, production rules, and logic statement. The interface provides interactive communication with the user, get information, and display ES recommendation. With an intelligent interface, a user of ES solves problems on the basis of relevant information. An expert system may be evaluated based on its expandability, responsiveness, costs, and the effectiveness of its ability to solve problems (interpret, predict, diagnose, design, plan, monitor, debug, repair, instruct, and control), interface with users, and handle knowledge (learn, represent, induce, and retrieve) [4].

Typical expert systems for manufacturing include the following:

- BETSY is an expert system for bearing selection.
- Dominic is conceived as a domain-independent program suitable for any design task which can be formulated as an optimization problem.

The Lathe Expert System (LES) was built to diagnose problems with a softwood plywood rotary veneer lathe.

3 Applications in Manufacturing

Applications of expert systems in manufacturing problem include design, process planning, assembly, quality control and

- ***Matthew N.O. Sadiku*** *is a professor emeritus in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas.*
- ***Kazeem B. Olanrewaju*** *is an assistant professor in the Department of Chemical Engineering at Prairie View A&M University, Prairie View, Texas*
- ***Sarhan M. Musa*** *is a professor in the Department of Electrical and Computer Engineering at Prairie View A&M University, Texas.*
(*This information is optional; change it according to your need.)*

operation, production management, scheduling, production automation, maintenance, machining, tools selection, machine selection, equipment layout, tool design, welding, advanced manufacturing, product development, and material handling. Some of these applications are discussed as follows [5-11].

- *Production Automation:* Manufacturers are attempting to have their manufacturing systems partially or fully automated in order to reduce labor costs, increase operation efficiency, and increase production rate. Application of expert systems in manufacturing automation encompass the spectrum from the design of the product through to automated manufacturing using a robot. In the broad area of robotics, expert systems are applicable in robot kinematics and design, robot selection, workplace layout, and maintenance. An expert control system can be designed to control an unmanned manufacturing cell in order to meet the operational requirements of a cellular manufacturing system.
- *Product Design:* The design process includes various tasks depending on the products to be designed, the manufacturing environments of products, and the creativity needed in the design. The design tasks may be categorized into the three levels: routine work, creative work, and intelligent work. Expert systems can be applied to the intelligent work if the design process is well understood and structured. Many expert systems have been developed using VLSI design, which has made much progress compared with machine design. Genuine design expert systems are still rare.
- *Machine Selection:* Expert system for machine selection is a simulation based approach in order to structure the solution search mechanism and to overcome the try and error aspect. Its primary function is to suggest resource modifications based on performance measures obtained through simulation.
- *Process Planning:* This is an act of preparing detailed processing documentation for the manufacture of a piece part or assembly. In part machining, process planning is the act of preparing detailed operational instructions to transform an engineering design into a final part. The development of expert systems for process planning is easier than for design. The functions of process planning are to determine the sequence of machine tools, clamping devices, cutting tools, etc. The input to the process planning system is the product information represented by the product drawings and/or product model designed by the CAD system. Some companies are developing process planning systems with the cooperation between expert system builders and users.
- *Production Control:* This is often regarded as the decision making and information transmission aimed at performing effective and economical manufacturing by utilizing the manufacturing resources. In process control, expert systems can be applied in areas such as near a man-machine interface and applications with a possibility of substantial damage or loss to the plant.
- *Production Planning:* The rapidly changing manufacturing environment requires to create production planning that is easily upgradable. This is a key element in the manufacturing cycle from design through production. It is very important in a manufacturing company because it provides key communication links from top management to manufacturing. It determines the basis for focusing the detail production resources to achieve the strategic objectives of the company. Expert system can easily manage production information and make decision.
- *Diagnosis:* Maintenance, repair, and diagnostics is a major area of manufacturing activity which is amenable to the application of expert systems. Since maintenance expertise is critical, expert systems can help management to capture the knowledge of their best operators, engineers, and maintenance staff so that it will be available at all times. The main function of diagnostic systems is to detect the abnormal state of the objects, and then estimate the causes of the abnormal state. Many expert systems for diagnosis have been developed and put into practice. This is due to the fact that the inference process is adaptable to the diagnosis of various types of machines. A common inference engine can be applied to the diagnosis of different machines by modifying the rules. Diagnostic expert systems for fault finding as opposed to fault prevention, i.e. they are invoked after a failure has occurred rather before.
- *Welding:* Welding is a complex joining process. Various welding processes are in use nowadays, namely arc welding, gas welding, resistance welding, thermit welding, ultrasonic welding, laser beam welding, electron beam welding, etc. The traditional wedding procedure may be long and expensive. It is necessary that welding operator have remarkable experience. Artificial Intelligence technology has much to offer the welding system automation. The expert system application in welding offers a set of behavioral characteristics for a welding control system that can increase the quality execution and reliability of welding activities.
- *Management:* An expert system designed for the use of different applications and different groups of users in the organization will involve managers, accountants, financial analysists, consultants, strategic planners etc. Due to community demand and modern business culture nowadays, developing expert system for the application for data and information management in organization is important.
- *Manufacturing Site Selection:* The need for the development of the prototype expert system site selection comes from state or local planners who must identify possible sites when asked by potential foreign manufacturing investors, who are looking for suitable loca-

tions for production plants. Site selection is one of the most crucial decisions that industrial management has to make in considering establishment of a new plant.

Other areas of application of expert systems in manufacturing include manufacturing process control, textile industry, steel industry, and construction industry.

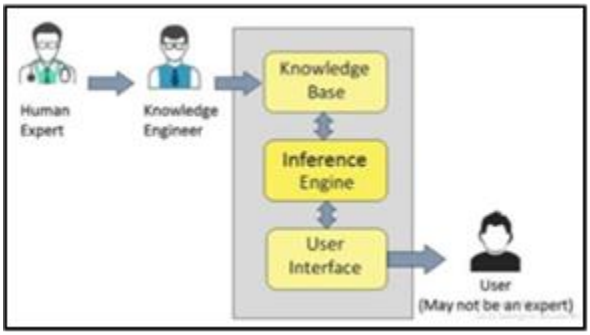

Figure 1 Structure of an expert system [3]

4 Benefits

An expert system is a computer program that employs expert knowledge to improve
decision-making performance in solving the problems of a specific domain area. Expert systems are one of the most successful tools of artificial intelligence. Domain-specific expert systems are being developed to aid the human decision maker. Expert Systems offer some benefits in different areas in manufacturing.

An expert system has a number of advantages over humans. They are a permanent component of the manufacturing system, whereas humans can retire or resign and take all their knowledge with them. They have a great potential impact on manufacturing efficiency. They are helpful in autonomous decision-making in broad domain spectrum.

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5 Limitations

The general limitations of ES occur in three primary areas: technology, choice and implementation of expert knowledge, and specification of the knowledge base [12]

- *Technology:* The size of the knowledge base is limited by current technology. The development of expert systems must cope with the current languages, since computers are unable to understand natural language.
- *Expert Knowledge:* The limitations arising from of expert knowledge include the following:
  - The development of expert systems requires an expert to spend time developing and debugging the system.
  - The system developer must choose an expert that can provide the appropriate expert information.
  - The knowledge base should include appropriate rules, heuristics, and optimization techniques.
  - The wrong rules or inappropriate use of the rules can lead to an ineffective system.
  - The determination of expert knowledge from the expert is a difficult process.
  - Expert system lacks creativity.

Knowledge Base: The systems do not have a general knowledge to fall back on if the specific knowledge is insufficient. The systems do not learn from their experience. The systems have little knowledge of their own scope and limitations. The system knowledge base is difficult to debug and remove redundancies.

6 Conclusion

An expert system refers to a computer program that can perform tasks in the domain of application, just like an human expert. It is essentially an artificial intelligence system that has been trained with real cases to perform complicated tasks and acts as a decision-support system. Expert systems are rapidly growing in application and usage worldwide. They have moved into engineering from their original application domains of chemistry, geology, mathematics, and medicine. Engineers have started to take interest in expert systems as tools for solving their problems.

One must recognize that manufacturing expert systems are different from those used in academic or healthcare environment. For more information about the uses of expert systems in manufacturing, one should consult the book in [13-22] and related journals which include:

- *Expert Systems*
- *IEEE Expert*
- *Expert Systems with Applications.*
- *Journal of Manufacturing Systems*
- *The International Journal of Advanced Manufacturing Technology.*

References

[1] M. N. O. Sadiku, Y. Wang, S. Cui, and S. M. Musa, "Expert systems: A primer," International Journal of Advanced Research in Computer Science and Software Engineering, vol. 8, no. 6, June 2018, pp. 59-62.

[2] S. H. Teng and J. T. Black, "An expert system for manufacturing cell control,"Computers & Industrial Engineering, vol. 17, nos 1-4, 1989, pp. 18-23.

[3] "Artificial intelligence - Expert systems," https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligence_expert_systems.htm

[4] L. C. Leung, W. A. Millter, and G. Okogbaa. "Evaluation of manufacturing expert systems: Framework and model," The Engineering Economist, vol. 37, no. 4, October 2007, pp. 293-314.

[5] K. Iwata, "Application of expert systems to manufacturing in Japan," The International Journal of Advanced Manufacturing Technology, vol. 3, 1988, pp. 23-37.
[6] H. Chtourou, W. Masmoudia, and A. Maalej, " An expert system for manufacturing systems machine selection," Expert Systems with Applications, vol. 28, 2005, pp. 461–467.
[7] E. D. Chio, "An expert system application in manufacturing," IFAC Proceedings Volumes, vol. 23, no. 3, September 1990, pp.75-78.
[8] C. F. Tan et al., "The application of expert system: A review of research and applications," ARPN Journal of Engineering and Applied Sciences, vol. 11, no. 4, February 2016, pp. 2448-2453
[9] D. Kiritsis, A review of knowledge-based expert systems for process planning. methods and problems," International Journal of Advanced Manufacturing Technology, vol. 10, 1995, pp. 240-262
[10] D. D. Ardayfio, D. Jing, and M. Hays, "Prototype expert systems for engineering design and manufacturing automation," SAE Transactions, 1987, vol. 96, section 2, 1987, pp. 1411-1426.
[11] S. Suh, M. P. Kim, and T. J. Kim, "ESMAN: An expert system for manufacturing site selection," Computers, Environment and Urban Systems, vol. 12, no. 4, 1988, pp. 239-252.
[12] D. E. O'leary, "Expert systems in production management," in B. Lev (ed.), Production Management: Methods and Studies. North-Holland, Elsevier Science Publishers, 1986, pp. 175-185.
[13] R. Maus and J. Keyes (eds.), The Handbook of Expert Systems in Manufacturing. New York : McGraw-Hill, 1991.
[14] J. W. Kaewert and J. M. Frost, Developing Expert Systems for Manufacturing : A Case Study Approach. New York: McGraw-Hill, 1990.
[15] E. Ifeachor (Editor), A. Starita, and A. Sperduti (eds.), Neural Networks and Expert Systems in Medicine and Healthcare. World Scientific, 1998.
[16] J. Liebowitz, The Handbook of Applied Expert Systems. Boca Raton, FL: CRC Press, 2019.
[17] C. T. Leondes (ed.), Fuzzy Logic and Expert Systems Applications. Academic Press, 1998.
[18] C. T. Leondes (ed.), Expert Systems: The Technology of Knowledge Management and Decision Making for the 21st Century. Academic Press, 2001.
[19] A. Mital and S. Anand (eds.) Handbook of Expert Systems Applications in Manufacturing Structures and Rules. Springer, 2013.
[20] S. Tzafestas (ed.), Expert Systems in Engineering Applications. Springer Verlag, 2012.
[21] H. R. Parsaei and M. Jamshidi (eds.), Design and Implementation of Intelligent Manufacturing Systems: From Expert Systems, Neural Networks, to Fuzzy Logic. Volume 6, Environmental and Intelligent Manufacturing Systems Series. Upper Saddle River, NJ: Prentice Hall PTR, 1995.
[22] D. N. Chorafas, Expert Systems in Manufacturing (Automation in Manufacturing). Van Nostrand Reinhold Computer, 1992.