Chapter XVII
Key Enabling Technologies

ABSTRACT

While computers have proven to be instrumental in the advancement of product design and manufacturing processes, the role that various technologies have played over the years can never be over-estimated. Because of the intimate involvement of computers in the product development chain, technologies that have severed as enablers are in many cases all software-oriented. There are a number of issues that a technology needs to address in better support of CAD, CAPP, CAM, CNC, PDM, PLM, and so forth. Knowledge acquisition and utilization is one of the top priorities and very often the first step of actions. Intelligent reasoning and optimization is another important task. More often than not, the optimization problems have multi-objectives and multi-constraints that are highly non-linear, discrete, and sometimes fuzzy.

Among the technologies that have been developed in the recent past are knowledge-based (expert) system, artificial neural network (ANN), genetic algorithm (GA), agent-based technology, fuzzy logic, Petri Nets, and ant colony optimisation. An expert system is a computer system which includes a well-organized body of knowledge in a bounded domain, and is able to simulate the problem solving skill of a human expert in a particular field. Neural networks are the techniques that can work by simulating the human neuron function, and using the weights distributed among their neurons to perform implicit inference. The genetic algorithms mimic the process of natural evolution by combining the survival of the fittest among solution structures with a structured, yet randomized, information exchange. Agent-based technology utilizes agents as intelligent entities capable of independently regulating, reasoning and decision-making to carry out actions and to achieve a
specific goal or a set of goals. This chapter discusses these four technologies together with some applications of these technologies. Also briefly mentioned are the fuzzy logic, Petri Nets, and ant colony optimization methods. The objective is not to give a detailed account for each of these technologies. Instead, the intention is to introduce the technologies that are relevant to and suitable for applications such as CAD, CAPP, CAM, CNC, PDM, and PLM, as well as their integrations. This chapter can also be considered as a focal place for those who are interested in the technologies to further explore, as a collection of over 130 research publications have been cited and are all listed in the reference list at the back.

KNOWLEDGE-BASED SYSTEMS

In the domain of product design, process planning and manufacturing, multiple types of human expertise and knowledge are needed for various decision-making processes. This explains why knowledge-based systems are among the most researched technologies, and in many cases have proven to be effective systems.

Expert Systems Technology

Expert system (otherwise known as knowledge-based system) is an important branch of artificial intelligence (AI). Expert systems provide a natural, yet powerful and flexible means for obtaining solutions to a variety of manufacturing problems that often cannot be dealt with by other more orthodox methods. One study reported an investment of over $100 million in artificial intelligence research by large American manufacturing companies. Some of them have achieved impressive results (Dornan, 1987). Among the companies that benefited the most are Digital Equipment Corporation’s XCON, Boeing and Lockheed Georgia Corporation’s GenPlan. It is of the view of many that expert systems can make a significant contribution to improving process and production planning (Kusiak & Chen, 1988, Badiru, 1992, Jayaraman & Srivastava, 1996, Zhang & Chen, 1999).

Welbank (1983) defines an expert system as a program that has a wide base of knowledge in a restricted domain, and uses complex inferential reasoning to perform tasks, as human expert usually does. In other words, an expert system is a computer system containing a well-organised body of knowledge, which emulates expert problem solving skills in a bounded domain of expertise. The system is able to achieve expert levels of problem solving performance, which would normally be achieved by a skilled human when confronted with significant problems in the domain. As illustrated in Figure 17.1, an expert system consists of three main components, the knowledge base, inference engine and user interface.

Knowledge base is the heart of the system. It contains the knowledge needed for solving problems in a specific domain. Knowledge may be in the form of facts, heuristics (e.g. experiences, opinions, judgments, predictions, algorithms) and relationships usually gleaned from the mind of experts in the relevant domain. Knowledge may be represented using a variety of representation techniques (e.g. semantic nets, frames, predicate logic) (Jackson, 1986, Ignizio, 1991, Mital & Anand, 1994), but the most commonly used technique is “if-then” rules, also known as production rules. These rules are often represented in a tabulated form. The inference engine is employed during a consultation session to examine the status of the knowledge base, handle the content of the knowledge base and
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