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Handbook of Computational Intelligence in Manufacturing and Production Management

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by natural processes in physics and biology. Evolutionary computing unlike conventional technique, have the robustness for producing variety of optimal solutions in a single simulation run, giving wider options for engineering design practitioners to choose from. Despite limitations, the act of finding the optimal solution for optimization problems has shown a substantial improvement in terms of reducing optimization process time and cost as well as increasing accuracy. This chapter provides an overview of the application of evolutionary computing techniques for engineering design optimization and the rational behind why industries and researchers are in favor of using it.

Section II
Supply Chain and Decision Support Systems

This chapter presents the general steps towards a methodology that contributes to the advancement of prediction and mitigation of undesirable supply chain behavior. Through the integration of tools such as system dynamics, neural networks, eigenvalue analysis, and sensitivity analysis, the proposed methodology captures the dynamics of the supply chain, detects changes and predicts the behavior based on these changes, and defines needed modifications to mitigate the unwanted behaviors and performance.

This chapter proposes a decision support system which analyses projects with respect to market, technicalities, and social and environmental impact in an integrated framework using analytic hierarchy process, a multiple attribute decision making technique. This not only reduces duration of project evaluation and selection, but also helps select an optimal project for the organization for sustainable development. The entire methodology has been applied to a cross-country oil pipeline project in India and its effectiveness has been demonstrated.

This chapter is devoted to modeling and analysis of supply chain systems. Supply chain management is more and more affected by network and dynamic business environment. Coordination and cooperation can significantly improve the efficiency of supply networks. The combination of network structure modeling and simulation of dynamic behavior of units in supply network can be a powerful instrument of performance analysis of supply networks. The problem of coordination in dynamic supply networks involves multiple units with multiple goals, which requires multicriteria analysis. Multicriteria analysis of supply network performance includes criteria such as quantity, quality, time, cost, and profit.

This chapter examines the application of system archetypes as a systems development methodology to create simulation models. The application of system archetypes to the strategic business analysis of a healthcare system reveals that it is possible to identify the lacuna in management's strategic thinking processes. In the research study, hospital executives found that policy modification with slight variable changes helps to avoid pitfalls in systems thinking and avoid potentially cost prohibitive learning had these policies been implemented in real life.

The provision of timely, accurate, relevant, and concise information for managerial decision making has traditionally represented a challenge to information systems designers. The mass adoption of enterprise resource planning (ERP) systems has multiplied the amount of data being recorded about the movement of inventory in the supply chain. However, this online information requires much off-line manipulation in order for it to be meaningful to managers. In addition, this data are based on physical structures and business models that evolve over time, and thus inevitably a gap opens between the virtual enterprise and reality. Despite the benefits of inventory visibility and expenditure control afforded by ERP systems, managers still require data from other, nonintegrated systems. In this chapter the authors present their research on decision-making support in two manufacturing organizations, with the objective of understanding how these integrated applications support the manager in achieving goals.

This chapter focuses on hardware/software, Web-based technologies, and managerial policy options in supporting e-business. More and more, internal applications are being moved from legacy systems into a more flexible Web-based environment. The issue concerning World Wide Web technologies is important to today's businesses. Decision making in this area is complex and needs to consider carefully the characteristics and needs of the entities employing these technologies. The research presented here compares performances and costs of technologies used to serve dynamic Web content.

This chapter elaborates the basic concepts underlying the development of Web-based decision support systems (DSS). The chapter introduces a Web-based decision support system for water resources management on a basin scale and also some evolving concepts like mobile agent technology to meet the

challenges and problems associated with traditional Web-based DSS. A better understanding of the key issues and concepts are stressed upon bring together analysts, modelers, and the end users in building a Web-Based DSS which is understandable, accessible, and acceptable to all.

Section III
Applications in Manufacturing and Production Management

Independent component analysis (ICA) is a statistical method for transforming an observed multidimensional random vector into components that are as independent as possible. This chapter introduces the background information, the theory of ICA, and several common algorithms such as fast ICA, kernel ICA, and constrained ICA. The algorithms are applied to mineral resources prediction and remote sensing imagery, where traditional methods cannot satisfy the complexity of the spatial data (prospecting geochemistry data, remote sensing data, etc.). The results show that some independent elements accord with the practical distribution better than conventional methods.

This chapter explores the scope of biologically inspired swarm intelligence (SI) into production management with special emphasis in two specific problems, such as vehicle routing and motion planning of mobile robots. Computer simulations undertaken for this study have also been included to demonstrate the elegance in the application of the proposed theory in the said real-world problems. The chapter examines the scope of ant colony optimization (ACO) algorithm and particle swarm optimization (PSO) in production management problems.

This chapter focuses on application of optimization tools and techniques in metal cutting-based manufacturing. The chapter assesses the status and scope of artificial neural network-based inferential model, generic algorithm (GA), simulated annealing (SA), and tabu search (TS)-based metaheuristic search strategies in metal cutting processes. A solution methodology for nonlinear response surface optimization is proposed for the benefits of selection of an appropriate technique. Specific application in a multiple response grinding process optimization problem using ANN, real-valued genetic algorithm, simulated annealing, and a modified tabu search is also provided for a clearer understanding of the settings, where the proposed methodology is being used.

develop a computer model of the strategic issues that influence the performance and competitiveness of manufacturing, and the results of a quantitative survey are used to understand the actual extent of the influences of various factors in the current situation.

Foreword

Artificial intelligence (AI) is simply a way of providing a computer or a machine to think intelligently like human beings. Since human intelligence is a complex abstraction, scientists have only recently began to understand and make certain assumptions on how people think and to apply these assumptions in order to design AI programs. It is a vast knowledge base discipline that covers reasoning, machine learning, planning, intelligent search, and perception building.

Traditional AI had the limitations to meet the increasing demand of search, optimization, and machine learning in the areas of large, biological, and commercial database information systems and management of factory automation for different industries such as power, automobile, aerospace, and chemical plants. The drawbacks of classical AI became more pronounced due to successive failures of the decade long Japanese project on fifth generation computing machines. The limitation of traditional AI gave rise to development of new computational methods in various applications of engineering and management problems. As a result, these computational techniques emerged as a new discipline called computational intelligence (CI).

Computational intelligence terminology was originated by Professor Lotif A. Zadeh. Since its inception in early 1990s, the topic has changed to a great extent concerning its content and applications. Earlier it was concerned with the fuzzy sets, neural networks. and genetic algorithms. Now, it consists of granular computing, neural computing, and evolutionary computing along with their interactions with artificial life, chaos theory. and others. Evolutionary computational technique includes genetic algorithms, evolutionary programming, and evolutionary strategies and genetic programming. Artificial neural networks mimic the biological information system. Evolutionary computing algorithms are used for optimization problems, and fuzzy logic as a basis for representing imprecise knowledge.

Computational intelligence tools have attracted the growing interest of researchers, scientists, engineers, and managers in a number of practical applications. These applications include engineering, business, and banking. It has emerged as a relatively new field of research and has been finding more and more applications in various areas. Fuzzy set theory is more useful for reasoning with imprecise data and knowledge. Neural networks are more applicable in machine learning, whereas genetic algorithms are most suitable for the areas of search and optimization but it is not so successful in handling real time problems.

The applications of CI are diverse, including medical diagnosis, data mining, design and manufacturing, production planning and scheduling systems, robots working in hazardous environments, autonomous vehicles, image matching, and control systems, just to mention a few for the service of mankind.

There are several advantages of CI over traditional approaches. These include conceptual simplicity, broad domains of applications, better performance than classical methods on real life problems, use of knowledge management and hybridization with other methods, parallelism, and capability to solve dynamic problems.

A lot of innovation has been noticed in manufacturing and production management in recent years, becoming a very important area in business today. Production management is an interesting mixture of managing people, sophisticated technology, and the applications of computational intelligence. The handbook addresses the latest and most important issues related to production management. This handbook primarily serves as one comprehensive source of information where business managers, professors, and researchers can look for disseminate technology and ideas, and gain knowledge through a variety of research topics including theoretical, experimental, and case studies. It focuses on applications of new developments of computational intelligence tools such as artificial neural networks, genetic algorithms, and artificial immune system and swarm optimization methods to various areas of management.

The present exploration on manufacturing and production management is thoroughly edited and reviewed for which it has become a "hallmark" for the user/readers to pave the way for better managerial perspective. I am inclined to believe that the topics discussed by professors, researchers, and professional managers of international repute would be globally useful for the purpose they have been written.

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Preface

Experts now believe that world-class performances by organizations in providing high-quality cost-competitive products and services are essential for survival in today's business environment. Organizations need to attain a competitive advantage which could be achieved through effective integration of technology strategy with business strategy (Sohal, Ramsay, & Samson, 1992; Sohal, Samson, & Weill, 1991).

Information technology has significantly changed companys' business strategy (Black & Lynch, 2001, 2004**)**. During the last two decades manufacturing and information technology has forced great changes in the ways businesses manage their operations in meeting the desired cost and quality of products and services, customer demands, competition, and other challenging situations. While the 19th century gave birth to the Industrial Revolution, the 20th century saw a new kind of revolution in the Information Technology Revolution. The Information Revolution deals with the development of technologies that allow quicker and cheaper transmission of data and images, and storage and retrieval of information. Integration of resources and business units has become more effective than ever primarily due to the development of enterprise wide information systems, the Internet, and Web-based information systems. Production and operations organizations have been the forerunners in the implementation of such information systems.

There are essentially two types of technologies in manufacturing and operational organizations: core and enabling technologies. The core technology is that technology that provides leverage to the organization to fulfill its mission and grow (Laugen, Acur, Boer, & Frick, 2005). For example, Toyota's core competency is its manufacturing technology, Cannon's is its printer motor technology, British Aerospace's is wing technology, while Boeing believes its core competency to be systems integration technology. On the other hand, enabling technologies are those that facilitate or assist the core technology in doing what it does best. An example of such technologies is information technologies that run the Toyota assembly line and call center specialists who assure that problems with information technology can be mitigated. Information technologies in manufacturing companies offer both operational and strategic benefits. The strategic benefit of IT includes enhanced competitive position, improved strategic flexibility, and facilitating manufacturing globalization.

During the past decade, the role of IT in production management changed from the back-office supporting tools to a strategic role. Strategic information systems (SIS) now play a critical role in helping organizations to increase production efficiency, and to be more effective and competitive. As the business environment is changing fast, the need for newer and more effective IT/IS is arising. In fact, there has been a constant demand on IT professionals for improved methodologies, design, and applications. Accordingly, the researchers are responding to this demand through computational intelligence, particularly focusing on neural networks (Haykin, 1994; Wang & Takefuji, 1993), genetic algorithms (Davis, 1987; Deb, 2001; Goldberg, 1989), evolutionary programming (Diego & Duc Truong, 2007; Konar &

Jain, 2001), artificial immune systems (Dasgupta, 1980; De Castro & Timmis, 2002), and fuzzy systems (Zadeh, 1965; Zimmermann, 1999).

IT/IS have tremendous impact on the productivity in both manufacturing and service organizations (Roth, 1996). Companies have implemented systems such as enterprise resource planning (ERP), MRP, EDI, and so forth over time for improving their productivity. The Internet has created a brand-new outlet from which firms can market and sell their goods and services. The enormous amount of information that is now available to consumers on the Internet is mind-boggling. Improvements in the Internet and communication technologies have led to increased globalization of businesses.

Effective production management is the key to business success. Undoubtedly, newer information technologies have and will have growing influence in future of production and operations field. This handbook focuses on new developments in computational intelligence in areas such as forecasting, scheduling, production planning, inventory control, and so forth. It offers a great theoretical challenge for researchers and, from practical point of view, plays a significant role in the successful operation of different fields of production management. The application of various tools, as described in the handbook, will lead to a rapid turn-around of jobs and minimization of in-process inventory, and thereby minimizing the overall cost of production. The handbook incorporates newer efficient optimization methods that have emerged recently, based on the evolutionary computing paradigms such as genetic algorithms, neural networks, simulated annealing (Aarts & Korst, 1989; Van Laarhoven & Aarts, 1987), artificial immune systems, ant-colony algorithm (Dorigo, Caro, & Gambardella, 1997), and swarm intelligence (Kennedy & Eberhart, 2001). These tools are currently being utilized for developing efficient methodologies for different engineering and management problems.

There is yet another reason for compiling this handbook: minimizing the conceptual gap of unbalanced view of IT between IT researchers and production professionals. In spite of numerous developments in methodological areas, IT professionals are very little aware of production technologies. Following the same logic, production management professionals are not fully aware of IT related developments. This handbook primarily serves as a single source where IT researchers and production professionals can look for technologies and ideas, and knowledge through a variety of research methods including theoretical, experimental, and case studies. The handbook introduces researchers to many computing methodologies applicable in both services and manufacturing sectors. It addresses new developments in the field of production management and new information related to software, while remaining a strong focus on the fundamental concepts.

Production management and the use of information technology have both been extensively researched over recent years. There is no comprehensive study of the extent of use of information technology in production and operations management area. Most of the studies reported in the production management area have been too specific in the conventional areas such as inventory control, project management, scheduling, and so forth. New research areas have emerged due to the development of computational intelligence tools. The managerial practices have seen a direction of new development of Internet, World Wide Web, network based computing, data sharing, and data mining. In contrast to other books, this book will focus on the integration between IT and production systems, with emphasis on the applicability to real-life problems.

ORGANIZATION OF THE BOOK

The handbook is organized into three sections: Section I: Computational Intelligence Methodologies; Section II: Supply Chain and Decision Support Systems; and Section III: Applications in Manufactur-

ing and Production Management. The book contains 23 chapters contributed by leading experts from various parts of the world.

A brief description of each of the chapters follows.

Chapter I discusses the present challenges on developing heuristics and metaheuristics for scheduling problems. Manufacturing scheduling offers a great theoretical challenge to researchers. Traditionally researchers emphasized on classical optimization methods such as linear programming and branch and bound method to solve scheduling problems. However, these methods have the limitation of tackling small-sized scheduling problems because of the consumption of high CPU time. As a result, heuristics, as well as various efficient optimization methods based on the evolutionary computing paradigms such as genetic algorithms, simulated annealing, and artificial immune systems, have been applied to scheduling problems for obtaining near optimal solutions. These computational tools are currently being utilized successfully in various engineering and management fields. The chapter briefly discusses the overview of these emerging heuristics and metaheuristics and their applications to the scheduling problems. Given the rise in attention by the researchers, more emphasis has been given to explore artificial immune systems in details.

Chapter 2 deals with the application of some artificial intelligence based random search algorithms like genetic algorithms, ant colony optimization, simulated annealing, artificial immune system, and tabu search to machine loading problems in flexible manufacturing system. Comparative performance evaluations of these techniques with the best existing heuristics based on standard benchmark dataset have been presented in this chapter.

Chapter III focuses on financial tools required in production management settings. Production and operation management requires specific financial tools in order to accomplish the functions of production planning, costing, investment appraisal, and so forth. Computational intelligence in those financial functions is needed for production forecasting, production planning and control, profit volume analysis, cost analysis, investment appraisal, and analysis. The chapter discusses advances of neural networks, expert systems, advanced statistical analysis and operational research methods, and various hybrid techniques. A strategic alignment model is derived for the adoption of financial applications in businesses.

Chapter IV investigates the decision process of manufacturing systems under uncertain conditions. The decision process needs a systematic approach to structure the system requirements and highlight the management preferences while considering vague criteria. In order to establish a suitable empirical approach for the decision process compatible with the current/future requirements, the analytical hierarchical process (AHP) is employed for structuring the criteria influencing the process choice. The application of the proposed AHP model for the selection of manufacturing process is demonstrated using numerical examples. In addition, due to dealing with vague data in the decision process, the uncertain criteria are characterized by typical fuzzy sets. The integrated fuzzy AHP is then analyzed within the boundary conditions of the fuzzy criteria using the Expert Choice software. The proposed model is intended to be generic in structure and applicable to many firms.

Within the constraints of certain shortages and backlogs in a deterministic production-inventory control model, Chapter V presents some mathematical models highlighting the complex nonlinearity constrained optimization problem with a view to achieving optimal solutions using modified real-coded genetic algorithms and simulated annealing. Some numerical examples and sensitivity analysis have been included towards achieving such optimal solutions.

Chapter VI addresses the different condition monitoring techniques using computational intelligence. The effectiveness of different aspects of condition monitoring of bearings has been tested using different techniques such as neural networks, thereby producing good results.

Chapter VII addresses the issues, challenges, and problems of demand forecasting of short lifespan products. Due to the limitation of SIMForecaster, the existing forecasting system, the authors identify some soft computing techniques for solving these problems. They also suggest the importance of evolutionary computing techniques including genetic algorithms in the context of integrated demand forecasting system.

Chapter VIII addresses the issue of data mining process and its application to manufacturing. The author suggests by illustrating some examples that data mining as a computational intelligence approach offers a great promise to manufacturing companies. He also feels that although it has been widely used in different industries, its use is limited and new to manufacturing. He also believes that data mining will occupy a mainstream application in manufacturing, thereby enhancing the capabilities in the organization.

Chapter IX presents an overview of evolutionary computing application for engineering design. An optimal design may be defined as the one that most economically meets its performance requirements. Optimization and search methods can assist the designer at all stages of the design process. The past decade has seen a rapid growth of interest in stochastic search algorithms, particularly those inspired by natural processes in physics and biology. Impressive results have been demonstrated on complex practical optimization of several schools of evolutionary computation. Evolutionary computing, unlike conventional technique, had the robustness for producing s variety of optimal solutions in a single simulation run, giving wider options for engineering design practitioners to choose from. Despite limitations, the act of finding the optimal solution for optimization problems has shown a substantial improvement in terms of reducing optimization process time and cost as well as increasing accuracy.

Chapter X presents some methodologies to capture the dynamics of supply chain, detect the changes, and thereby predict the behavior on these changes and finally define the needed modification to mitigate the unwanted behaviors and performance. The authors describe these methodologies through the integration of system dynamics, neural networks, eigen value analysis, and sensitivity analysis tools that contribute to the advancement of prediction and mitigation of undesirable supply chain behavior within short- and long-term horizons. Finally, a case study has been briefly summarized in this context.

In Chapter XI, a decision support system is proposed to analyze projects with respect to market, technicalities, and social and environmental impact in an integrated framework using analytic hierarchy process, a multiple attribute decision making technique. This not only reduces duration of project evaluation and selection, but also helps select an optimal project for the organization for sustainable development. The entire methodology has been applied to a cross-country oil pipeline project in India and its effectiveness has been demonstrated.

Chapter XII addresses the issues relating to the modeling and analysis of dynamic supply networks. The author uses the combination of network structure modeling and simulation of dynamic behavior to enhance the performance analysis of supply networks.

Chapter XIII presents a case study where system archetypes are applied to create simulation models in healthcare with a view to identifying the loop holes in management strategic thinking processes and defying these fallacies during implementation.

Chapter XIV addresses the problems and challenges of a manufacturing integrated information system for managerial decision making. The authors present their research work on decision support systems in two manufacturing organizations where ERP have been implemented successfully with a view to facilitating manager's role in bridging the gap between the ERP system in supply chain and the real-world business organization.

Chapter XV discusses the issue concerning the importance of wide Web technologies in today's business, which is playing an increasing role in the communication of people. The author compares

different Web technologies to decide their best implementation with respect to performance and cost. The authors claim that a broader scope approach due to continuing developments in Web technologies is suggested for comparative analysis.

Chapter XVI elaborates the key concepts and technical issues concerning the development of Web-based decision support systems (DSS). The Web-based DSS enhances communication and decision-making capability in a distributed environment or a multiple stakeholder process. The authors present the application of Web-based DSS to water resources management on a basin scale. The authors hope that better understanding of these concepts of Web-based DSS will bring together participants like analysts, modelers, and the end users.

Chapter XVII discusses different independent component analysis (ICA) algorithms and their application to manufacturing problems. Since it was difficult to satisfy the complexity of prediction of spatial data on mineral resources and remote sensing imagery by the conventional methods, the ICA method has paved the way for futuristic research in spite of having its some limitations and disadvantages.

Chapter XVIII describes the methodology of a biologically inspired swarm intelligence technique and its application to some production management problems such as vehicle routing and motion planning of mobile robots. Computer simulation for these problems has been included.

Chapter XIX identifies the existing challenges in the application of optimization techniques for any metal cutting-based manufacturing unit. The authors review the scope and status of artificial neural networks and metaheuristic strategies in metal-cutting process. Subsequently, a solution methodology based on these tools has been proposed. Finally, the authors present a case study in a multiple response grinding process optimization problem using these tools.

Chapter XX describes an investigation of an integrated approach combining optical camera data and intelligent algorithms to overcome the limitation of single-perspective triangular sensors for laser scanning of 3D surfaces.

Chapter XXI describes the uses of data mining for forecasting data management needs for the selected biotechnology data of forest cover data and human lung cancer data set. Four data mining software have been used to obtain enhanced intelligent capabilities for biotechnology research. The proposed tools and techniques can be utilized in a typical manufacturing and production environment.

Chapter XXII addresses the importance of a networked supply chain model, which is the combination of Web and supply chain management technology. As a result, supply chain costs will be reduced along with the increase in customer satisfaction. Finally, the authors present a case study on supply chain management enhancing the effectiveness of the organization.

Chapter XXIII discusses system a dynamics modeling approach and a quantitative survey approach to model interactions in manufacturing systems. Modeling is a great tool to analyze long-term consequences of policy options in manufacturing. Models could be used for understanding the intertwined relationships among factors which influence the performance and competitiveness of manufacturing. The system dynamics approach is used to develop a conceptual model of the strategic issues that influence the performance and competitiveness of manufacturing, and the results of a quantitative survey are used to understand the actual extent of the influences of various factors in the current situation.

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* * *

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Narendra S. Chaudhari has obtained a PhD, MTech (computer science), and BTech in electrical engineering (with distinction) degrees from I.I.T. Bombay in 1988, 1983, and 1981, respectively. For his doctoral work, he worked on graph isomorphism problem where, besides other heuristic approaches, he developed an approach for strongly distinguishing regular graphs based on interior point approach (applied on polytopes defined on eigenspaces of graphs). He has been fellow, Institute of Electronics and Telecom Engineers (IETE), India since 2000. He has a varied experience in industry and R&D organizations, and he had been with Devi Ahilya University, Indore, India from 1988 to 2001. Since 2001, he has been with Division of Information Systems, School of Computer Engineering (SCE), Nanyang Technological University (NTU), Singapore, and currently he is an associate professor. He has more than 145 publications and four books to his credit. He has supervised more than fifteen PhDs in computer science and engineering. His current research interests are in the areas of game AI, specialized neural networks (e.g., binary neural networks), fuzzy inference, optimization algorithms, computational learning, and theoretical computer science. He teaches courses on discrete structures, algorithms, database systems, formal languages, automata and computability, programming languages, and compiler construction.

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