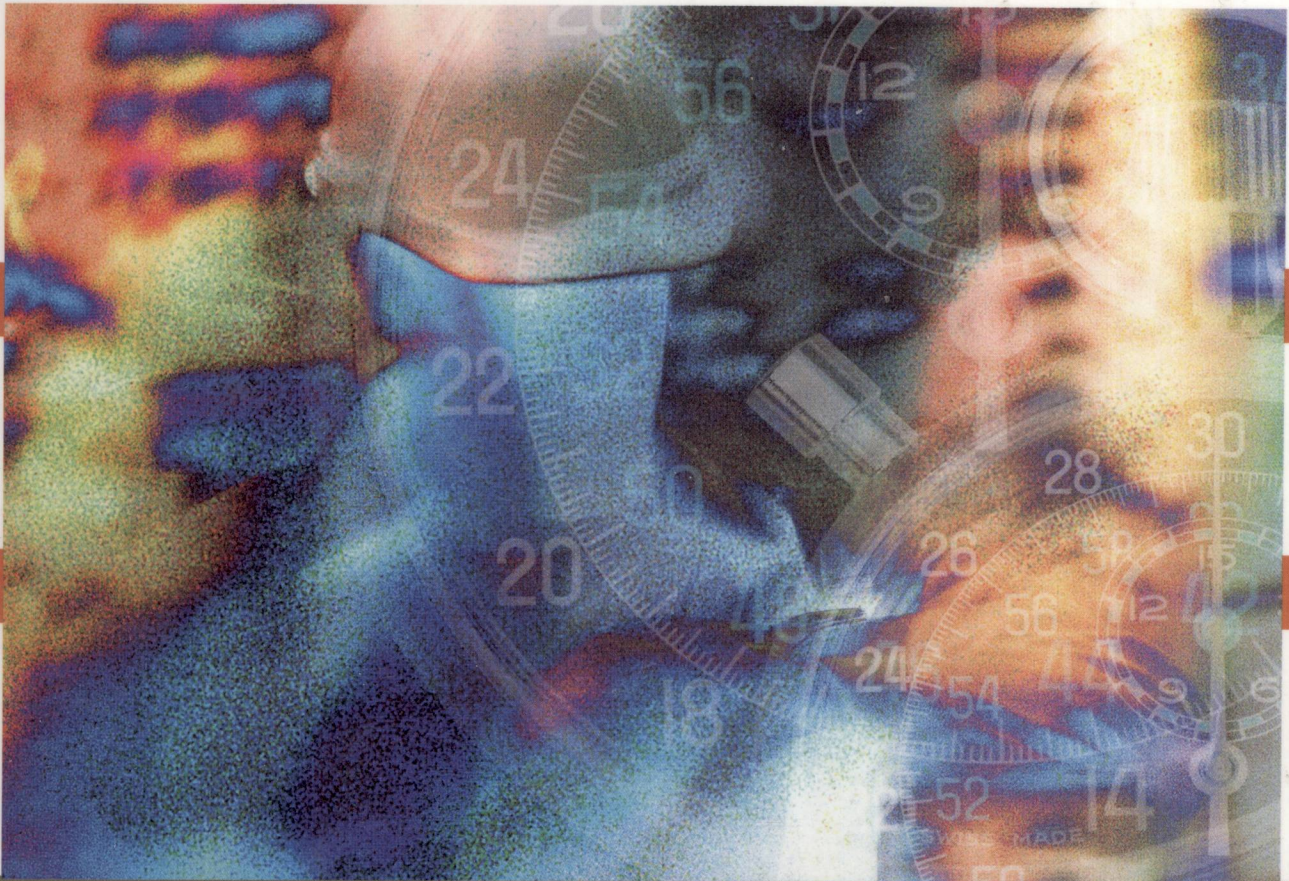


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Handbook of Computational Intelligence in Manufacturing and Production Management



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Handbook of Computational Intelligence in Manufacturing and Production Management

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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 begun 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.

Angappa “Guna” Gunasekaran, PhD
University of Massachusetts, Dartmouth

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 companies' 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 a 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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July 2007

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Section I

Computational Intelligence Methodologies

Table of Contents

Foreword	xiv
Preface.....	xvi
Acknowledgment	xxiii

Section I **Computational Intelligence Methodologies**

Chapter I

Heuristics and Metaheuristics for Solving Scheduling Problems / <i>Dipak Laha</i>	1
---	---

Chapter II

Solving Machine Loading Problem of FMS: An Artificial Intelligence (AI) Based Random Search Optimization Approach / <i>Anoop Prakash, Nagesh Shukla, Ravi Shankar, and Manoj Kumar Tiwari</i>	19
--	----

Chapter III

Computational Intelligence in the Financial Functions of Industrial Firms / <i>Petros Theodorou and Dimitrios Karyampas</i>	44
--	----

Chapter IV

Fuzzy Sets and Analytical Hierarchical Process for Manufacturing Process Choice / <i>M. Reza Abdi</i>	63
--	----

Chapter V

Computational Intelligence Approach on a Deterministic Production-Inventory Control Model with Shortages / <i>Supriyo Roy, S. Mukhopadhyay, and P. P. Sengupta</i>	83
---	----

Chapter VI

Condition Monitoring Using Computational Intelligence / <i>Tshilidzi Marwala and Christina Busisiwe Vilakazi</i>	106
--	-----

Chapter VII

Demand Forecasting of Short Life Span Products: Issues, Challenges,
and Use of Soft Computing Techniques / *Narendra S. Chaudhari and Xue-Ming Yuan*..... 124

Chapter VIII

Introduction to Data Mining and its Applications to Manufacturing / *Jose D. Montero*..... 144

Chapter IX

Evolutionary Computing in Engineering Design / *Rajkumar Roy, Ashutosh Tiwari, Joseph Tafasse Azene, and Gokop Goteng*..... 167

Section II

Supply Chain and Decision Support Systems

Chapter X

Towards a Methodology for Monitoring and Analyzing the Supply Chain Behavior /
Reinaldo Moraga, Luis Rabelo, and Alfonso Sarmiento 186

Chapter XI

Decision Support System for Project Selection / *Prasanta Kumar Dey*..... 209

Chapter XII

Modeling and Coordination of Dynamic Supply Networks / *Petr Fiala*..... 227

Chapter XIII

Modeling with System Archetypes: A Case Study / *Mahendran Maliapen* 249

Chapter XIV

Integrated Manufacturing Applications and Management Decision Making:
Putting the P Back into ERP / *Fergal Carton and Frédéric Adam*..... 263

Chapter XV

Planning and Deployment of Dynamic Web Technologies for
Supporting E-Business / *John A. Hines* 281

Chapter XVI

Web-Based Decision Support System: Concept and Issues / *Rajib Goswami
and Pankaj Barua* 300

Section III
Applications in Manufacturing and Production Management

Chapter XVII

Independent Component Analysis and its Applications to Manufacturing Problems /
Xian-Chuan Yu, Ting Zhang, Li-Bao Zhang, Hui He, Wei Zou, and Meng Yang..... 316

Chapter XVIII

Swarm Intelligence in Production Management and Engineering / *Swagatam Das*
and Amit Konar..... 345

Chapter XIX

Artificial Neural Network and Metaheuristic Strategies: Emerging Tools
for Metal Cutting Process Optimization / *Indrajit Mukherjee and Pradip Kumar Ray* 366

Chapter XX

Intelligent Laser Scanning of 3D Surfaces Using Optical Camera Data / *A. Denby,*
J. F. Poliakoff, C. Langensiepen, and N. Sherkat 398

Chapter XXI

Using Data Mining for Forecasting Data Management Needs / *Qingyu Zhang*
and Richard S. Segall..... 419

Chapter XXII

Supply Network Planning Models Using Enterprise Resource Planning Systems /
Sundar Srinivasan and Scott E. Grasman..... 437

Chapter XXIII

Modeling and Analysis for Production Performance: Analysis of U.S. Manufacturing
Companies / *Purnendu Mandal and Enrique (Henry) Venta*..... 454

About the Contributors 475

Index 486