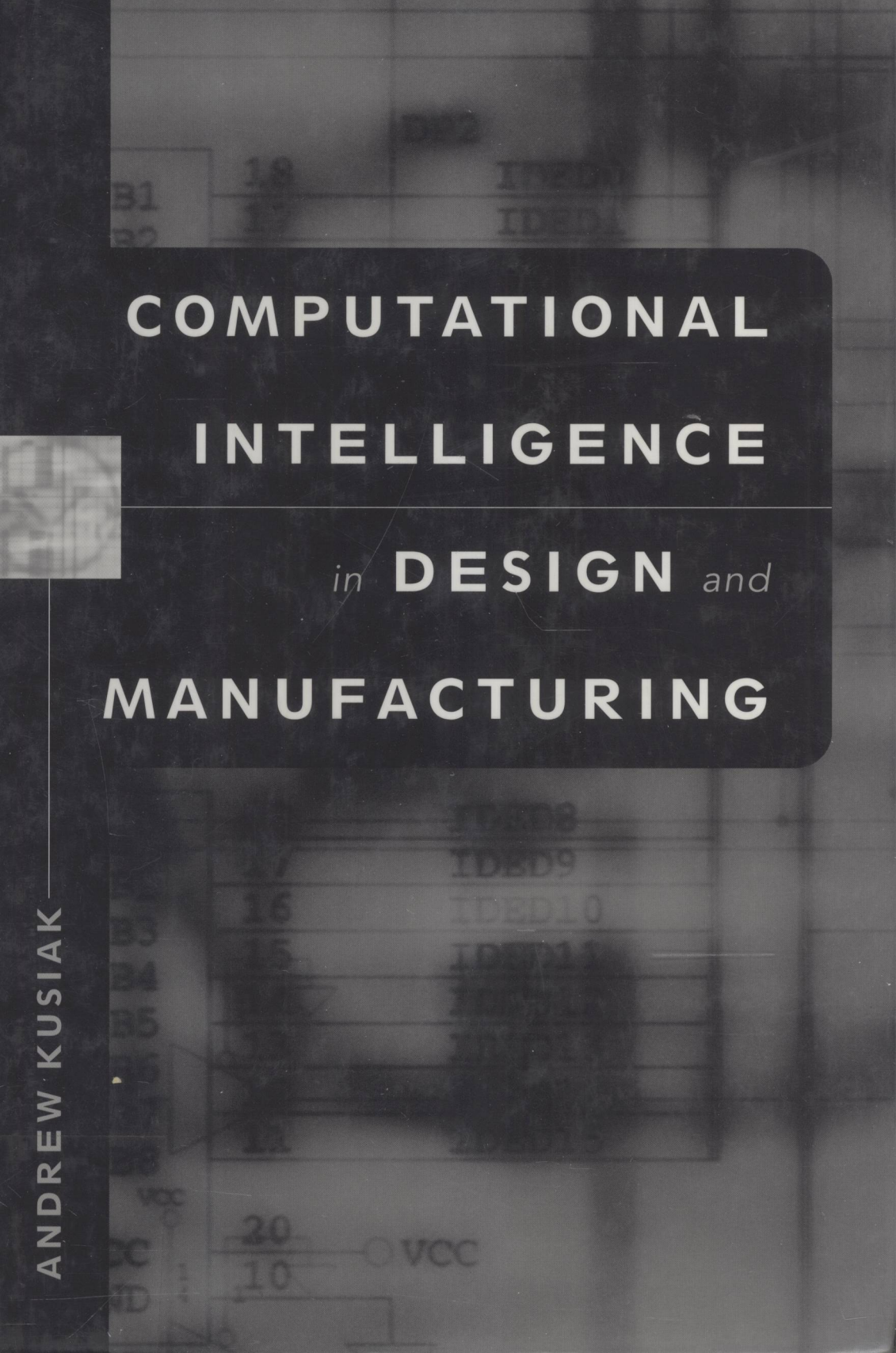
COMPUTATIONAL
INTELLIGENCE
in DESIGN and
MANUFACTURING
ANDREW KUSIAK

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COMPUTATIONAL INTELLIGENCE IN DESIGN AND MANUFACTURING

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PREFACE

The industry is undergoing profound changes, with knowledge being on the forefront of business success. An enterprise of the future will be highly computerized, and its competitiveness will be expressed with knowledge-related measures. Much tighter integration will be seen across diverse functional areas such as product development, manufacturing, supply chain, and customer satisfaction as well as external liaisons. An enterprise of the future is likely to be agile, extended, virtual, model and knowledge based, and integrated in time and space.

The goal of this book is to present recent advances in modeling and applying computational methods to enterprises. The emphasis is on model integration and using computational intelligence approaches to solve problems across many areas of an enterprise. No single formalism, technique, or tool can generate useful decisions in a modern enterprise; rather, a magnitude of carefully crafted computational intelligence approaches are needed. It is important that the models and solution approaches appeal to a human user who irrespective of the degree of automation and computerization becomes a focus.

The material included in the 17 chapters of this book falls into three categories: (1) background on principles of basic functional areas ranging from the design of parts and process planing to manufacturing systems design and production management; (2) models and computational intelligence tools and techniques applicable to all functional areas; and (3) examples and case studies based on actual industrial projects.

Chapter 1 introduces the reader to the basic functional areas and technologies of a modern enterprise. It discuses issues ranging from manufacturing technology to computational aspects, design concerns, standards, and organizational issues.

Chapter 2 falls into the category of computational tools and discusses knowledge-based systems with all the details important in an industrial environment. Based on the content presented in this chapter, a reader should be able to design comprehensive intelligent application. The knowledge-based content of this chapter is utilized to a various degree in the subsequent chapters.

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Chapter 3 is concerned with features that are a medium between a product and a manufacturing process. Features are fundamental to communication between design, manufacturing, and other functional systems and human experts working in these areas. As parts and products might be designed in one enterprise, manufactured in another, and yet distributed by a third enterprise, proper attention has to be given to the forms and standards related to the product and part information. Although the chapter emphasizes mechanical parts and metal-cutting processes, the presented principles apply to other components and processes as well.

Chapter 4 discusses the application of reason maintenance in conceptual design of products. Early use of the features defined in the previous chapter in the design of a product is a good indicator of its success. The design of parts making up a product is often expressed with the futures, being transformed by process plans (Chapter 5) into manufacturing features.

Chapter 5 presents a comprehensive set of models and techniques useful in process planning. Knowledge-based and optimization approaches are seamlessly integrated into a comprehensive computational framework. The content of this chapter can be easily applied to almost any other process, for example, electronics or health care.

Waist is an enemy of any business, including manufacturing. A dominant way of waist manifestation in manufacturing is through excessive setup costs. Formal ways for reducing the setup costs by design and management strategies are discussed in Chapter 6.

Chapter 7 contains a comprehensive treatment of key operational areas, production planning, capacity balancing, and manufacturing scheduling. The functionality of widely used production planning systems is discussed. Capacity balancing could be a function of an MRP or an ERP system or a stand-alone application. Models reflecting various objectives and constraints are discussed for discrete manufacturing systems. Scheduling models and algorithms ranging from the simple ones to the most comprehensive and applicable to almost any system are broadly discussed.

The production planning concepts included in Chapter 7 fall into the class of "push" systems, while Chapter 8 deals with various forms of kanban systems representing the "pull" production concept. This chapter provides information on issues pertaining to design and operations of kanban systems for various processes.

The first eight chapters deal largely with the definition of the interface between design parts and manufacturing and management and operations issues in manufacturing systems. The next seven chapters emphasize manufacturing system design. This group of chapters begins with Chapter 9, discussing formal approaches to the selection of manufacturing equipment and reduction of unnecessary manufacturing resources. The latter falls into the "waist" elimination category of problems discussed in Chapter 6 in the context of setups.

Chapter 10 introduces the reader to one of the most widely recognized issues in manufacturing—group technology. Over years group technology has been fundamental in different business initiatives ranging from classification and coding to just-in-time, focused manufacturing, and lean concepts. Despite wide coverage in the literature, group technology appears to be not well understood. This chapter presents

a comprehensive set of models that can be applied in any manufacturing setting. This wealth of information can be utilized far beyond the manufacturing sector, as it breaks complex problems into manageable pieces based on well-justified principles.

Chapter 11 introduces two most widely used types of neural networks, backpropagation and self-learning networks. The concepts and algorithms are illustrated with numerical examples, mostly in the group technology context. The analogy of neural networks to expert systems and fuzzy systems is provided.

Chapter 12 discuses models and algorithms for determining layout of machines and facilities. It is shown that differences exist between models for machine and facility layout as well as the layout pattern depends on the type of material handling system. High computational complexity of the layout problems implies that only heuristic algorithms are practical. Exploiting special properties of the layout models has led to the development of computationally efficient heuristic algorithms.

Chapter 13 is an industrial case study demonstrating a model for allocation of inventory. The model presented in the chapter provides for a proper balance of the space requirement for in-process storage and final stage inventory. Issues that are related to reengineering the storage space layout and material handling optimization are considered.

The two previous chapters dealt with layout of manufacturing facilities, emphasizing machines, material handling systems, and inventory space. In Chapter 14 an industrial case study involving the design of a warehouse is described. A computational procedure for determining layout of a class-based warehouse is developed.

In a typical industrial practice, the relationship between design and manufacturing is not well articulated. The design for a manufacturing paradigm is normally limited to manufacturing processes. Chapter 15 discusses foundations of design in a much broader context—design for agility. The concept of improving manufacturing operations through design of products and systems is discussed.

In modern manufacturing activities outside of a design and manufacturing floor are as important as the design and manufacturing activities itself. The case study discussed in Chapter 15 illustrates application of a systems engineering approach to the development of a tool for supplier evaluation.

Chapter 17 presents fundamentals of data mining methodology, which is growing in popularity as a viable tool for extracting meaningful content from large volumes of data and information. Data mining is compared with other computational methodologies. Basic models and algorithms for data mining and data farming are presented.

The book is written to meet the needs of senior undergraduate and graduate engineering students, designers, systems analysts, managers, and other practitioners. As the book emphasizes modeling, analysis, and computational methods, it will be of interest to numerous disciplines, including industrial, mechanical, electrical, and systems engineering. Significant portions of the material apply to the service sector.

The main motivation of writing this book comes from multiyear collaboration with various industries. The book content reflects the needs of mechanical, electronics, and

software companies as well as numerous service organizations, including health care. Many examples and case studies presented in the book are coming from industry. The models and algorithms presented have been widely used in practical applications.

Although most of the material presented in this book is based on the author's personal research conducted over many years, some material presented was a result of collaborative projects. The author expresses appreciation to many colleagues, visiting researches, and graduate students with whom he has collaborated in recent years. The ideas on setup reduction and features are due to my collaboration with J. Feng and P. G. Li. The design for agility rules were developed jointly with D. He. Y. K. Chung's research is reflected in the neural network content of this book. Collaborative research with C. C. Huang was fundamental to the presentation of the concept of kanban systems. My thanks to K. Park and for his collaboration on topics related to group technology and machine layout algorithms. R. Vujosevic and E. Szczerbicki have contributed ideas on product synthesis. Finally, the research of my former graduate student T. N. Larson was instrumental in the preparation of industrial case studies.

Many thanks go to my undergraduate and graduate students and many colleagues from industrial corporations and participants of professional seminars and workshops for discussing various ideas incorporated in the book.

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