

Applying Computational Intelligence

Arthur K. Kordon

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How to Create Value

 Springer

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To my friends

Preface

In theory, there is no difference between theory and practice. But, in practice, there is.

Jan L.A. van de Snepscheut

The flow of academic ideas in the area of computational intelligence has penetrated industry with tremendous speed and persistence. Thousands of applications have proved the practical potential of fuzzy logic, neural networks, evolutionary computation, swarm intelligence, and intelligent agents even before their theoretical foundation is completely understood. And the popularity is rising. Some software vendors have pronounced the new machine learning gold rush to “Transfer Data into Gold”. New buzzwords like “data mining”, “genetic algorithms”, and “swarm optimization” have enriched the top executives’ vocabulary to make them look more “visionary” for the 21st century. The phrase “fuzzy math” became political jargon after being used by US President George W. Bush in one of the election debates in the campaign in 2000. Even process operators are discussing the performance of neural networks with the same passion as the performance of the Dallas Cowboys.

However, for most of the engineers and scientists introducing computational intelligence technologies into practice, looking at the growing number of new approaches, and understanding their theoretical principles and potential for value creation becomes a more and more difficult task. In order to keep track of the new techniques (like genetic programming or support vector machines) one has to Google or use academic journals and books as the main (and very often the only) sources of information. For many practitioners, the highly abstract level and the emphasis on pure theory of academic references is a big challenge. They need a book that defines the sources of value creation of computational intelligence, explains clearly the main principles of the different approaches with less of a focus on theoretical details and proofs, offers a methodology of their integration into successful practical implementations, and gives realistic guidelines on how to handle the numerous technical and nontechnical issues, typical for real-world applications.

Motivation

Applying Computational Intelligence is one of the first books on the market that fills this need. There are several factors that contributed to the decision to write such a book.

The first is to emphasize the different forces driving academic and industrial research (see Fig. 0.1).

Value is the basis of the different modes of operation between academic and industrial research. The key objective of academic research is to create new knowledge at any level of Nature (from quantum to cosmos) and the definition of success is the quality and quantity of publications. In contrast, the key objective of industrial research is to create value by exploring and implementing knowledge from almost any level of Nature. The definition of success is increased profit and improved competitive position in the market.

Since the value factor in industry is a question of survival, it has a dominant role and dictates different ways of doing research than in the academic world. University professors can satisfy their curiosity at any level and depth of the knowledge ladder even without funding. Industrial researchers don't have this luxury and must concentrate on those levels of the knowledge ladder where the profit is maximal. As a result, assessment of value creation in almost any phase of industrial research is a must. Unfortunately, this important fact is practically ignored in the literature and one of the goals of this book is to emphasize the decisive role of value creation in applying emerging technologies, like computational intelligence, in practice.

The second factor that contributed to the decision to write this book, is to clarify the drastic changes in doing applied science in the last 10 years. Once upon a time there were industrial laboratories, such as Bell Labs, with a broad scientific focus and almost academic mode of operation. Not anymore. Globalization and the push of shareholders for maximal profit has significantly transformed applied research

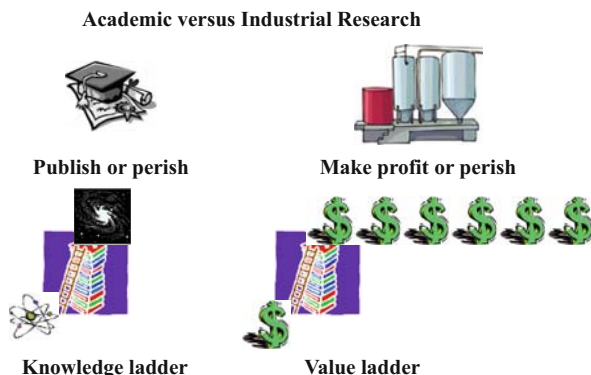


Fig. 0.1 Different driving forces between academic and industrial research

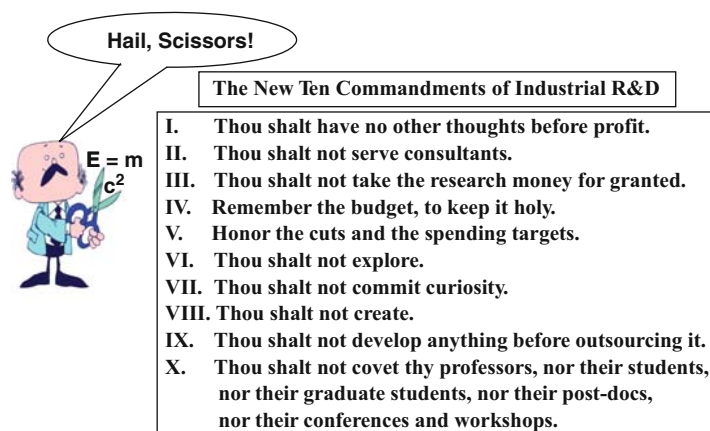


Fig. 0.2 The new Ten Commandments of Industrial R&D

into the direction of perpetual cuts and short-term focus. A satirical view of the current *modus operandi* is presented in the new Ten Commandments of Industrial R&D, shown in Fig. 0.2.

The cost reduction crusade imposed a new strategy for applying emerging technologies, which assumes minimal exploratory efforts. As a result, the new methodology for applied research must significantly reduce the risk and the time for introducing new technologies. Unfortunately, the known solutions are *ad hoc*, and there's little experience of developing adequate application strategies. One of the goals of the book is to offer a systematic approach for practical implementation of emerging technologies with low total-cost-of-ownership, appropriate in the current environment of lean industrial R&D.

The third factor that contributed to the decision to write this book is the broad experience of the author in applying computational intelligence in a global corporation, such as his employer, The Dow Chemical Company. With the collective efforts of talented researchers, visionary managers, and enthusiastic users, Dow Chemical became one of the industrial leaders in opening the door to the advantages of computational intelligence. In this book, the key learning from this accumulated knowledge is shared with the academic and industrial community at large – although I will skip details that may endanger Dow Chemical's intellectual property. In addition, all given examples are based on publicly available sources.

Purpose of the Book

Computational intelligence is relatively new to industry. It is still a fast-growing research area in the category of emerging technologies. On top of that, computational intelligence is based on a smorgasbord of approaches with very different

theoretical bases, such as fuzzy logic, neural networks, evolutionary computation, statistical learning theory, swarm intelligence, and intelligent agents. Promoting it in a consistent and understandable way to a broader nontechnical audience is a challenge. Unfortunately, this significantly reduces the number of future users and the application potential of computational intelligence. Another issue is the unsystematic and *ad hoc* ways of implementing most of the known applications. In summary, it is not a surprise that a comprehensive book on applied computational intelligence is not available.

The purpose of the book is to fill this need, to address these issues and to give guidelines to a broad audience on how to successfully apply computational intelligence. The key topics of the book are shown in the mind-map in Fig. 0.3 and are discussed next:

1. *How to broaden the audience of computational intelligence?* The first main topic of the book focuses on the ambitious task of broadening the audience of potential users of computational intelligence beyond the specialized communities, as is now the case. The main computational intelligence methods will be explained with minimal mathematical and technical details, and with an emphasis on their unique application capabilities.
2. *How to create value with computational intelligence?* The second key topic of the book clarifies the most important question in practical applications – the issue of value creation. The answer covers: identifying the sources that make computational intelligence profitable; defining the competitive advantages of the technology relative to the most widespread modeling methods in industry; and analyzing the limitations of the approach.
3. *How to apply computational intelligence in practice?* The third key topic of the book covers the central point of interest – the application strategy for

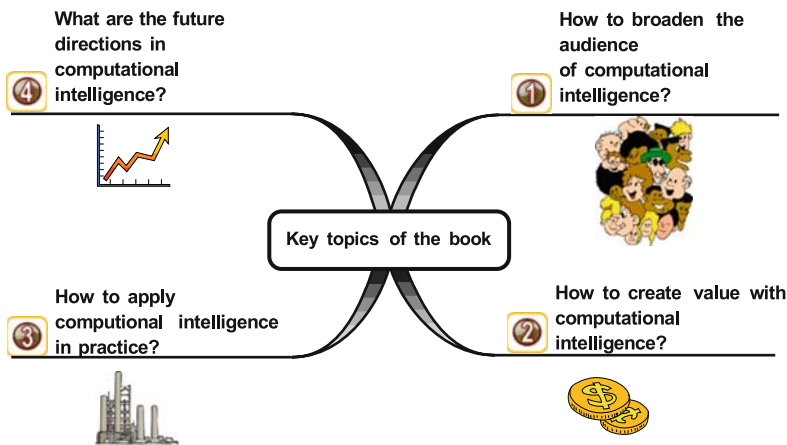


Fig. 0.3 Main topics of the book

- computational intelligence. It includes methodologies for integration of different technologies, marketing computational intelligence, specific steps for implementing the full application cycle, and examples of specific applications.
4. *How to evaluate the future directions in computational intelligence?* The fourth main topic of the book addresses the issue of the sustainability of applied computational intelligence in the future. The potential for growth is based on the promising application capabilities of new approaches, still in the research domain, and the expected increased demand from industry.

Who Is This Book for?

The targeted audience is much broader than the existing scientific communities in computational intelligence. The readers who can benefit from this book are presented in the mind-map in Fig. 0.4 and are described below:

- *Industrial Researchers* – This group includes scientists in industrial labs who create new products and processes. They will benefit from the book by understanding the impact of computational intelligence on industrial research, and by using the proposed application strategy to broaden and improve their performance. In addition, they will know how to leverage the technology through proper marketing.
- *Practitioners in Different Businesses* – The group consists of the key potential final users of the technology, such as process engineers, supply-chain organizers, economic analyzers, medical doctors, etc. This book will introduce the main

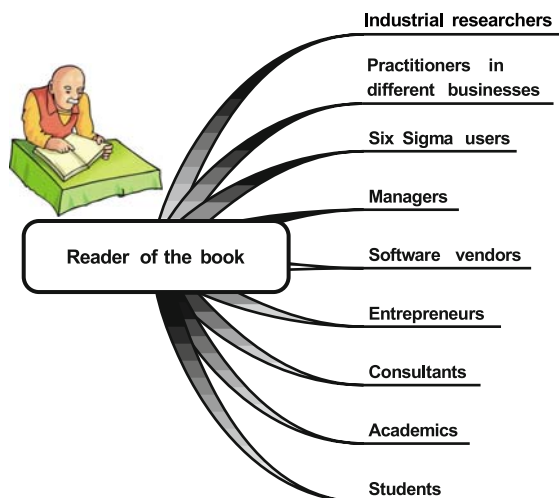


Fig. 0.4 Potential readers of the book

computational intelligence technologies in a language they can understand, and it will encourage them to find new applications in their businesses.

- *Six Sigma Users* – Six Sigma is a work process for developing high-quality solutions in industry. It has been accepted as a standard by the majority of global corporations. The users of Six Sigma are estimated to be in the tens of thousands of project leaders, called black belts, and hundreds of thousands of technical experts, called green belts. Usually they use classical statistics in their projects. Computational intelligence is a natural extension to Six Sigma in solving complex problems with a nonlinear nature, and both black and green belts can take advantage of that.
- *Managers* – Top-level and R&D managers will benefit from the book by understanding the mechanisms of value creation and the competitive advantages of computational intelligence. Middle- and low-level managers will find in the book a practical and nontechnical description of this emerging technology, which can make the organizations they lead more productive.
- *Software Vendors* – The group includes two types of vendors – of generic software for the development of computational intelligence systems, and of specialized software that uses appropriate computational intelligence techniques. Both groups will benefit from the book by better understanding the market potential for their products in this field.
- *Entrepreneurs* – This class consists of enthusiastic professionals who look to start new high-tech businesses, and venture capitalists who are searching for the Next Big Thing in technology investment. The book will give them substantial information about the nature of computational intelligence, its potential for value creation, and the current and future application areas. This will be a good basis for developing business plans and investment strategy analysis.
- *Academics* – This group includes the large class of academics who are not familiar with the research and technical details of the field and the small class of academics who are developing and moving computational intelligence ahead. The first group will benefit from the book by using it as an introduction to the field and by understanding the specific requirements for successful practical applications, defined directly from industrial experts. The second group will also benefit from the book through better awareness of the economic impact of computational intelligence, understanding the industrial needs, and learning about the details of successful practical applications.
- *Students* – Undergraduate and graduate students in technical, economics, medical, and even social disciplines can benefit from the book by understanding the advantages of computational intelligence and its potential for implementation in their specific fields. In addition, the book will help students to gain knowledge about the practical aspects of industrial research and the issues facing real-world applications.

How This Book Is Structured

The structure of the book with its organization in parts and chapters is given in Fig. 0.5.

Part I of the book is a condensed nontechnical introduction of the main technologies of computational intelligence. Chapter 1 clarifies the differences between

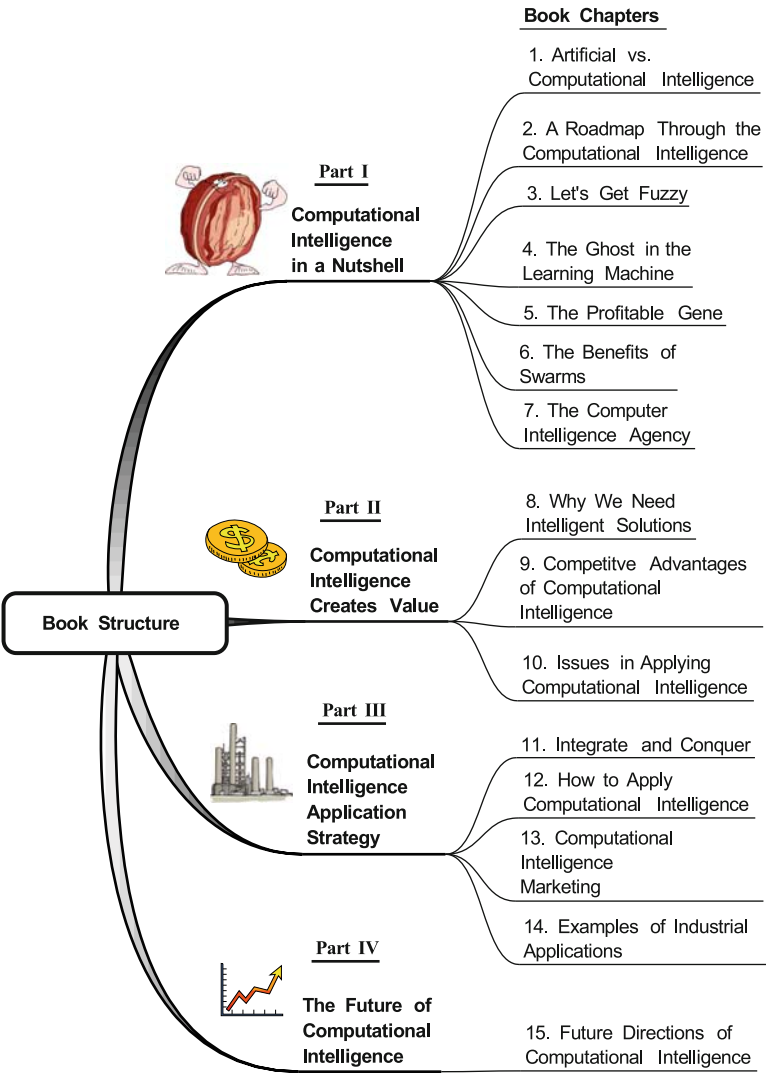


Fig. 0.5 Structure of the book

artificial intelligence and its current successor, while Chap. 2 presents an overview of the technologies and their key scientific principles. The key technologies are introduced in the next five chapters: Chap. 3 describes the main features of fuzzy systems; Chap. 4 introduces neural networks and support vector machines; Chap. 5 gives an overview of the different evolutionary computation techniques; Chap. 6 presents several methods based on swarm intelligence; and Chap. 7 describes the key capabilities of intelligent agents.

Part II focuses on the value creation potential of computational intelligence. It includes three chapters: Chap. 8 identifies the main application areas of computational intelligence; Chap. 9 defines the competitive advantages of this new emerging technology relative to the main, current research approaches in industry, such as first-principles modeling, statistics, heuristics, and classical optimization; finally the issues involved in applying computational intelligence in practice are discussed in Chap. 10.

Part III covers the most important topic of the book – defining an implementation strategy for successful real-world applications of computational intelligence. Chapter 11 emphasizes the critical importance of integrating different research approaches in industrial applications, and gives several examples of efficient integration; Chap. 12 presents the main steps of the application strategy and gives guidelines for the large group of Six Sigma users; Chap. 13 concentrates on the critical issue of computational intelligence marketing; and Chap. 14 gives specific examples of applications in manufacturing and new product design.

Finally, Part IV addresses the future directions of computational intelligence. Chapter 15 gives an introduction to the new technologies in computational intelligence, and looks ahead to the expected demands from industry.

What This Book Is NOT About

- *Detailed Theoretical Description of Computational Intelligence Approaches* – The book does not include a deep academic presentation of the different computational intelligence methods. The broad targeted audience requires descriptions that involve a minimal technical and mathematical burden. The reader who requires more detailed knowledge on any specific approach is forwarded to appropriate resources such as books, critical papers, and websites. The focus of the book is on the application issues of computational intelligence and all the methods are described and analyzed at a level of detail that enables their broad practical implementation.
- *Introduction of New Computational Intelligence Methods* – The book does not propose new computational intelligence methods or algorithms for the known approaches. The novelty in the book is on the application side of computational intelligence.
- *Software Manual of Computational Intelligence Approaches* – This is not an instruction manual for a particular software product – the interested reader is

directed to the corresponding websites. The author's purpose is to define a generic methodology for computational intelligence applications, independent of any specific software.

Features of the Book

The key features that differentiate this book from the other titles on computational intelligence are defined as:

1. *A Broader View of Computational Intelligence* – One of the main messages in the book is that focusing only on the technology and ignoring the other aspects of real-world applications is a recipe for failure. The winning application strategy is based on three key components – scientific methods, infrastructure, and people. We call it the Troika of Applied Research, shown in Fig. 0.6.

The first component (People) represents the most important factor – the people involved in the whole implementation cycle, such as researchers, managers, programmers, and different types of final users. The second component (Methods), where most of the current analysis is focused, includes the theoretical basis of computational intelligence. The third component (Infrastructure) represents the necessary infrastructure for implementing the developed computational intelligence solution. It includes the required hardware, software, and all organizational work processes for development, deployment, and support. Promoting this broader view of computational intelligence, and especially clarifying the critical role of the human component for the success of practical applications, is the leading philosophy in the book.

2. *Balancing Scientific Purity with Marketing* – An inevitable requirement for broadening the audience of computational intelligence is changing the presentation language from technical jargon to nontechnical English. Unfortunately, some of the theoretical purity and technical details are lost in this translation.

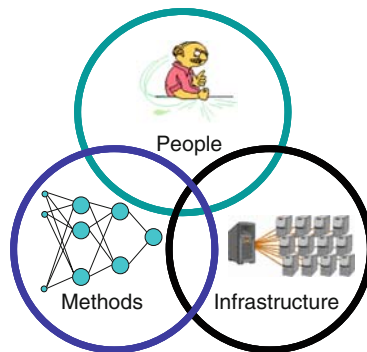


Fig. 0.6 The Troika of Applied Research

In principle, marketing-type language is much simpler and more assertive. The author is prepared for criticism from the research community but is firmly convinced of the benefits of changing the style to address nontechnical users.

3. *Emphasis on Visualization* – The third key feature of the book is the widespread use of different visualization tools, especially mind-maps¹ and clip art.² We strongly believe that nothing presents a concept better than a vivid visualization.

Mind-mapping (or concept mapping) involves writing down a central idea and thinking up new and related ideas that radiate out from the center.³ By focusing on key ideas written down in your own words, and then looking for branches out and connections between the ideas, one can map knowledge in a manner that will help in understanding and remembering new information.

¹The mind-maps in the book are based on the product ConceptDraw MindMap (<http://www.conceptdraw.com/en/products/mindmap/main.php>).

²The clip art in the book is based on the website <http://www.clipart.com>.

³A good starting book for developing mind-maps is: T. Buzan, *The Mind-map Book*, 3rd edition, BBC Active, 2003.

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Lake Jackson Texas
March 2009

Arthur K. Kordon

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