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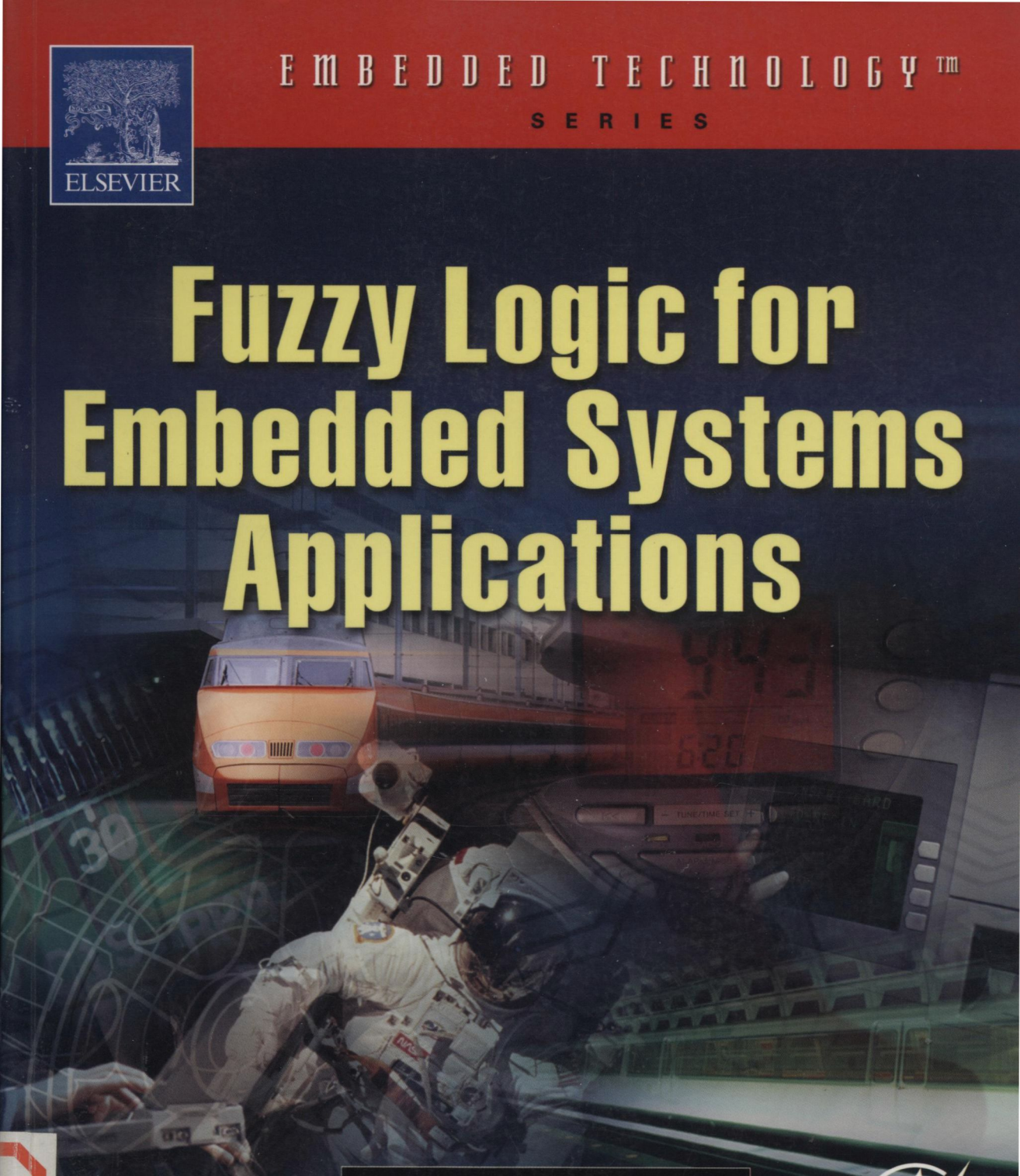
Fuzzy Logic for Embedded Systems Applications



Ahmad M. Ibrahim

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FUZZY LOGIC
for Embedded Systems Applications

by

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FUZZY LOGIC
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Preface

Fuzzy logic and its applications are now well-established and arguments for and against it have reached a steady state. There is an overwhelming volume of literature on the topic making it a difficult task for a practicing engineer, beginner researcher, or an advanced student to grasp the topic and then apply the acquired knowledge with only a small investment of time and money. This book is intended to present fuzzy logic and its applications for embedded systems succinctly yet comprehensively, with a self-contained, simple, readable approach. Simplicity here means the omission of extraneous sentences and phrases, and the exclusion of non-applied mathematical and research-oriented details. It is intended for the intelligent reader with an alert mind. The approach, the organization, and the presentation of this book are also hoped to enhance the accessibility to existing knowledge beyond its contents. An extensive bibliography not only of printed material but also of annotated Web links is provided at the end of each chapter.

The book is divided into nine chapters in addition to a set of quizzes, an appendix, a list of symbols and acronyms, and a glossary. Chapter 1 gives an overview of embedded systems and their implementation techniques. The chapter introduces the wide scope of embedded systems. The relationship between fuzzy logic and embedded systems is also outlined.

Chapters 2 and 3 introduce succinctly the concepts of fuzzy sets, fuzzy operations, and fuzzy relations with illustrative examples. The discussion is geared toward what would be needed in order to design fuzzy embedded systems.

In Chapter 4, embedded fuzzy logic applications are introduced with simplified case studies. Contrasting fuzzy logic control with conventional control is emphasized. It is hoped that by the end of this chapter that the reader would be able to apply fuzzy logic to the design of an embedded system of interest. The reader may wish to consult Chapter 8, Fuzzy Software Tools, select a few tools and start experimenting with fuzzy systems design and simulation.

A critique of fuzzy logic is presented in Chapter 5, a topic that is not commonly discussed in the engineering literature on fuzzy logic. It is, however, important for engineers to understand the limitations and implications of any methodology they intend to use. No tool is suitable for everything; it must be used skillfully within its

bounds of applicability. Moreover, most engineers are interested in intellectual discussions relevant to the topic at hand as long as the ideas are communicated properly and to the point. The discussion in this chapter is brief, but with an extensive bibliography provided for those who may like to further research any of the points discussed.

Chapter 6 presents the fundamentals of artificial neural networks, which are closely related to fuzzy logic but with fundamentally different concepts. The chapter introduces basic structures and learning algorithms of neural networks.

Hardware realizations are outlined in Chapter 8, which discusses both analog and digital implementations. Chapter 9 provides the reader with an opportunity to gain hands-on experience with a minimum investment of time and money. The chapter gives an overview of numerous software tools for fuzzy logic systems, neural networks, and neuro-fuzzy systems. The software reviewed includes C, C++, and Java source codes, in addition to M-files for MATLAB. Design and analysis software tools with graphical user interfaces are also discussed, as well as software that is meant to demonstrate fundamental concepts. All software tools, or working demos of them, are available for downloading through the Web along with documentation and examples in most cases.

Since most of the ideas presented are now well established there are no references given within the chapter text. However, further reading and expansion on the information presented is facilitated by the selected bibliography provided at the end of each chapter. The Web resources selected are those available at no charge, relevant to the topics discussed, and expected to be reliable.

The idea of citing references from the Web does not yet hold wide acceptance in some academic circles. The major argument against the idea is the questionable reliability of the content and its sustained availability. It should be remembered that content does not become reliable just because it is printed on paper, and unreliable when it is posted freely on the Web. Nevertheless, many of the resources cited as accessible through the Web are documents that were published on paper as well, and the Web simply enhances their availability. The use of the Web is essential for some of the resources such as interactive demos. It should also be remembered that books are known to go out of print and many may not be physically accessible with ease. Of course, an available, well written book constitutes a better and more convenient source of knowledge. Accessibility through the Web would be the next best thing, but it requires guidance, as provided here, to make the most out of it.

The set of quizzes with answers provided is meant to help the reader ponder about the subjects introduced without being side-tracked from the final goal that could be better reached by using the resources of chapter 9; thus learning through practice.

The appendix introduces the fundamental concepts of Genetic Algorithms (GAs). It is an optimization technique sometimes used in conjunction with the design of fuzzy and neural systems. A classified, annotated Web bibliography is provided for the reader who may wish to study the topic further.

A list of symbols and acronyms is provided along with the circuit symbols of MOSFETs that appear in literature on fuzzy logic embedded implementations to help the reader avoid possible confusion when consulting the resources.

A glossary of terms related to embedded systems, fuzzy logic and neural networks is provided. Although it refers to terms used in the various chapters of the book, it also introduces some terms to expand the coverage and provoke further interest in the general topic.

If an instructor is to use this book as a teaching resource, numerous application-oriented exercises and mini-projects can be assigned to the students if the instructor wishes to do so. For example:

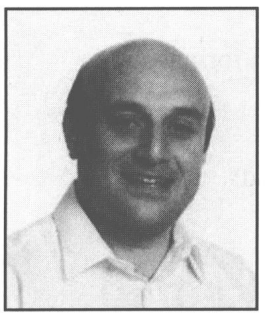
- The quizzes provided could be the basis for class discussion on the fundamentals of fuzzy logic and neural networks.
- An item from the numerous Web resources provided could be selected and students asked to research it further and expand on the short review given.
- Students could be asked to research entries from the glossary further.
- Students could be asked to run a selected demo simulation or Java applet from the resources provided in Chapter 9, observe its action, document their observations, and relate it to the theory.
- Students could be assigned a system of interest such as a refrigerator, vacuum cleaner, auto-focus, level control, speed control, etc. They could identify the inputs and outputs, design a linguistic model, then simulate it using one of the tools discussed.
- Students could be also asked to produce their own source code and executable file to solve one of the above problems.
- A topic from Chapter 5, Fuzzy Logic Critique, could be selected for further research and discussion.

It is hoped that through this book the reader will:

- Gain an understanding of the wide range of embedded systems and their future trend.
- Be able to use fuzzy sets and fuzzy logic algebra.
- Recognize when and why it would be advantageous to use fuzzy logic.
- Understand the fundamentals of neural networks and recognize when it is advantageous to use them.
- Gain familiarity with the hardware implementation approaches of fuzzy logic for embedded systems applications.
- Be able to experiment with the design of fuzzy systems for embedded systems applications.
- Be able to pursue further details of a topic within fuzzy logic embedded systems applications with relative ease.

I would like to express my gratitude to Dr. Alexander Berezin, McMaster University, Hamilton, Ontario, Canada for his encouragement and useful discussions. I would also like to thank Dr. Lawrence Hulsman, University of Arizona, Tucson, USA for his continuous encouragement and inspiration. The comments provided by Mahmoud Gadala, Senior Engineer, Pratt & Whitney Canada Inc, Montreal, Quebec, Canada are highly appreciated. I would also like to thank Dr. Ahmed Hussein, University of Northern British Columbia, Prince George, British Columbia, Canada, Dr. Erol Inelmen, Bogazici University, Istanbul, Turkey, Prof. Predrag Pesikan, DeVry, Mississauga, Ontario, Canada, and Dr. Aleksander Malinowski, Bradley University, Peoria, Illinois, USA; their interest and input are particularly valued.

About the Author



Dr. Ibrahim is a senior member of the Institute of Electrical and Electronics Engineers (IEEE), a member of the Association of Professional Engineers of Ontario (APEO), the Material Research Society (MRS), the American Association of Engineering Education (ASEE), and the International Banknote Society (IBS). He lectured in the area of electronics on three continents to a diverse population of students and presented seminars and workshops to practicing engineers.

He has a wide range of publications including papers in refereed journals and conferences. Dr. Ibrahim has organized and chaired sessions on *Current Trends in Electronics Education* during the IEEE Conferences IECON'01, Denver, Colorado, USA, and IECON'02, Sevilla, Andalucia, Spain. He was a guest editor for the 2003 Special Issue of the International Journal of Engineering Education on *Current Trends in Electronics Education.* He was a member of the International Advisory Committee of the First and Second International Conferences on Distanc Learning held at the Belarussian State University of Informatics and Radioelectroi s, Minsk, Belarus in the years 2001 and 2002. Dr. Ibrahim has a B.Sc. (EE) degree from Ain Shams University, Cairo, Egypt, and a Masters (Eng. Phys.) and Ph.D. (EE) degrees from McMaster University, Hamilton, Ontario, Canada. At present he is a senior professor at DeVry, Mississauga, Ontario, Canada.

What's on the CD-ROM?

Included on the accompanying CD-ROM:

- A fully searchable eBook version of the text in Adobe pdf format
- Links to numerous useful fuzzy-related web sites
- Additional informative resources and documents

Access the Read_Me file for more details on the CD-ROM contents.

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