To C. A. Rosen and C. W. Stork

Preface

O ur purposes in writing this Second Edition — more than a quarter century after the original — remain the same: to give a systematic account of the major topics in pattern recognition, based whenever possible on fundamental principles. We believe that this provides the required foundation for solving problems in more specialized application areas such as speech recognition, optical character recognition, signal analysis, and so on. Since 1973, there has been an immense wealth of effort, and in many cases progress, on the topics we addressed in the First Edition. The pace of progress in algorithms for learning and pattern recognition has been exceeded only by the improvements in computer hardware. Some of the outstanding problems acknowledged in the First Edition have been solved, whereas others remain as frustrating as ever. Taken with the manifest usefulness of pattern recognition, this makes the field extremely vigorous and exciting.

While we wrote then that pattern recognition might appear to be a rather specialized topic, it is now abundantly clear that pattern recognition is an immensely broad subject, with applications in fields as diverse as speech recognition, optical character recognition, handwriting and gesture recognition, lipreading, geological analysis, document searching and the recognition of bubble chamber tracks in elementary particle accelerators; it central to a host of man-machine interface problems, such as pen-based computing. The size of the current volume (which precluded material on scene analysis, included in the first edition) is a testament to the body of established theory. Whereas we expect most of our readers will be interested in developing pattern recognition systems, perhaps a few will be active in understanding existing pattern recognition systems, most notably human and animal nervous systems. To address the biological roots of pattern recognition would of course be beyond the scope of this book. Nevertheless, as neurobiologists and psychologists interested in pattern recognition in the natural world continue to rely on more advanced mathematics and theory, they too may profit from the material presented here.

Despite the existence of a number of excellent books that focus on a small set of specific *techniques*, we feel there is still a strong need for a book such as ours, which takes a somewhat different approach. Rather than focus on a specific technique such as neural networks, we address a specific *class of problems* — pattern recognition problems — and consider the wealth of different techniques that can be applied to it. Students and practitioners typically have a particular problem and need to know which technique is best suited. Books focusing on neural networks may not explain decision trees, or nearest-neighbor methods, or many other classifiers to the depth required by the pattern recognition practitioner who must decide among the various

techniques. Such books organized around a technique first and foremost generally fail to provide deeper understanding of any single technique, understanding that comes from exploring the relationships among various techniques.

These developments demanded a unified presentation in an updated edition of Part I of the original book. We have tried not only to expand but also to improve the text in a number of ways:

New material The text has been brought up to date with chapters on pattern recognition topics that have, over the past decade or so, proven to be of value: neural networks, stochastic methods, genetic algorithms, theory of learning, to name a few. While the book continues to stress methods that are statistical at root, for completeness we have included material on syntactic methods as well. "Classical" material has been included, such as Hidden Markov Models, model selection, combining classifiers, useful results from the theory of learning, and so forth.

Examples Throughout the text we have included worked examples, usually containing data and methods simple enough to avoid tedious calculations yet complex enough to illustrate important points. These are meant to impart intuition, clarify the ideas in the text, and to help students solve the homework problems. In addition, in response to popular demand, a Solutions Manual has been prepared to help instructors who use this book in a course.

Algorithms Some pattern recognition or learning techniques are best explained with the help of algorithms, and thus we have included several throughout the book. These are meant for clarification, of course; they provide only the skeleton of structure needed for a full computer program. We assume every reader is familiar with such pseudocode, or can understand it from context here.

Starred Sections The starred sections (*) are a bit more specialized, and are generally expansions upon other material. Such material is not needed to understand subsequent un-starred sections, and thus they can be skipped on first reading.

Computer Exercises These are not specific to any language or system, and thus can be done in the language or style the student finds most comfortable.

Problems New homework problems have been added, organized by section earliest section where the material is covered.

Chapter Summaries Chapter summaries are included to highlight the most important concepts covered in the rest of the text.

Graphics We have gone to great lengths to produce a large number of high-quality figures and graphics to illustrate our points. Some of these required extensive calculations, selection and reselection of parameters to best illustrate the concepts at hand. Study the figures too! Faculty adopting this book for courses can contact the publisher in order to obtain a master set of the figures for making overhead transparencies. These are invaluable for teaching.

Mathematical Appendixes It comes as no surprise that students do not have the same mathematical background, and for this reason we have included mathematical appendixes on the foundations needed for the book. We have striven to use clear notation throughout — rich enough to cover the key properties, yet

simple enough for easy readability. The list of symbols in the Appendix should help those readers who dip into an isolated section that uses notation developed much earlier.

This book surely contains enough material to fill a two-semester upper-division or graduate course; alternatively, with careful selection of topics, faculty can fashion a one-semester course. A one-semester course could be based on Chapts. **??** – **??**, **??** & **??** (most of the material from the First Edition, augmented by neural networks and machine learning), with or without the material from the starred sections.

Because of the explosion in research developments, our historical remarks at the end of most chapters are necessarily cursory, and somewhat idiosyncratic. Our goal has been to stress important references rather than a complete historical record, to help the reader more than acknowledge, praise and cite the established researcher.

This book could never have been written without the support and assistance of several institutions. First and foremost is of course Ricoh Silicon Valley (DGS and PEH). Its support of such a long-range and broadly educational project as this book — amidst the rough and tumble world of industry and its never ending need for products and innovation — is proof positive of a wonderful environment and a rare and enlightened leadership. The enthusiastic support of Morio Onoe, who was Director of Research, Ricoh Company Ltd. when we began our writing efforts, is gratefully acknowledged. Likewise, San Jose State University (ROD), Stanford University (Departments of Electrical Engineering, Statistics and Psychology), The University of California, Berkeley Extension, The International Institute of Advanced Scientific Studies, the Niels Bohr Institute and the Santa Fe Institute (DGS) all provided a temporary home during the writing of this book. Our earnest gratitude goes to all.

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Portola Valley, California

David G. Stork
Richard O. Duda
Peter E. Hart