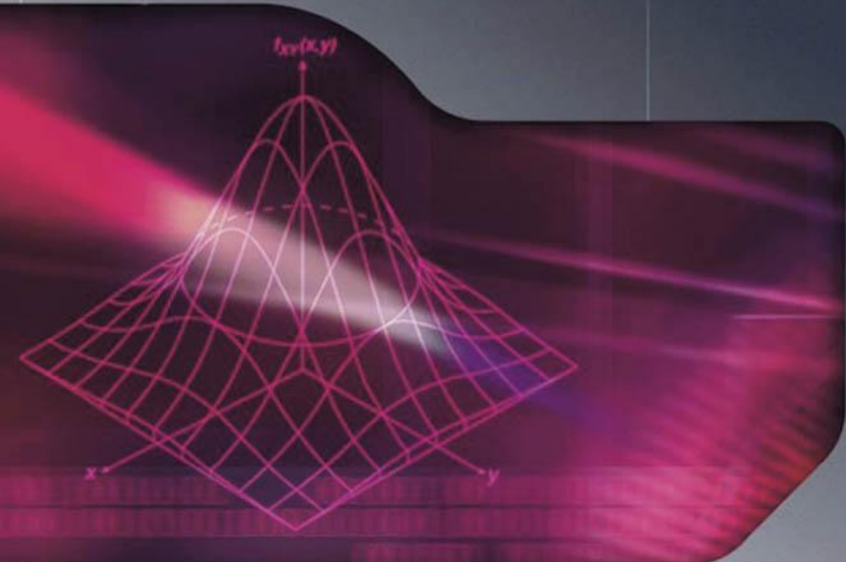
FUNDAMENTALS OF PROBABILITY AND STATISTICS FOR ENGINEERS



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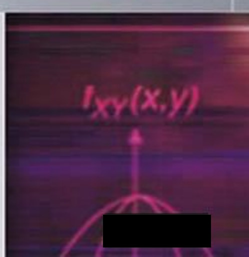

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To the memory of my parents

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Contents

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Preface

This book was written for an introductory one-semester or two-quarter course in probability and statistics for students in engineering and applied sciences. No previous knowledge of probability or statistics is presumed but a good understanding of calculus is a prerequisite for the material.

The development of this book was guided by a number of considerations observed over many years of teaching courses in this subject area, including the following:

- As an introductory course, a sound and rigorous treatment of the basic principles is imperative for a proper understanding of the subject matter and for confidence in applying these principles to practical problem solving. A student, depending upon his or her major field of study, will no doubt pursue advanced work in this area in one or more of the many possible directions. How well is he or she prepared to do this strongly depends on his or her mastery of the fundamentals.
- It is important that the student develop an early appreciation for applications. Demonstrations of the utility of this material in nonsuperficial applications not only sustain student interest but also provide the student with stimulation to delve more deeply into the fundamentals.
- Most of the students in engineering and applied sciences can only devote one semester or two quarters to a course of this nature in their programs. Recognizing that the coverage is time limited, it is important that the material be self-contained, representing a reasonably complete and applicable body of knowledge.

The choice of the contents for this book is in line with the foregoing observations. The major objective is to give a careful presentation of the fundamentals in probability and statistics, the concept of probabilistic modeling, and the process of model selection, verification, and analysis. In this text, definitions and theorems are carefully stated and topics rigorously treated but care is taken not to become entangled in excessive mathematical details.

Practical examples are emphasized; they are purposely selected from many different fields and not slanted toward any particular applied area. The same objective is observed in making up the exercises at the back of each chapter.

Because of the self-imposed criterion of writing a comprehensive text and presenting it within a limited time frame, there is a tight continuity from one topic to the next. Some flexibility exists in Chapters 6 and 7 that include discussions on more specialized distributions used in practice. For example, extreme-value distributions may be bypassed, if it is deemed necessary, without serious loss of continuity. Also, Chapter 11 on linear models may be deferred to a follow-up course if time does not allow its full coverage.

It is a pleasure to acknowledge the substantial help I received from students in my courses over many years and from my colleagues and friends. Their constructive comments on preliminary versions of this book led to many improvements. My sincere thanks go to Mrs. Carmella Gosden, who efficiently typed several drafts of this book. As in all my undertakings, my wife, Dottie, cared about this project and gave me her loving support for which I am deeply grateful.

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Introduction

At present, almost all undergraduate curricula in engineering and applied sciences contain at least one basic course in probability and statistical inference. The recognition of this need for introducing the ideas of probability theory in a wide variety of scientific fields today reflects in part some of the profound changes in science and engineering education over the past 25 years.

One of the most significant is the greater emphasis that has been placed upon complexity and precision. A scientist now recognizes the importance of studying scientific phenomena having complex interrelations among their components; these components are often not only mechanical or electrical parts but also 'soft-science' in nature, such as those stemming from behavioral and social sciences. The design of a comprehensive transportation system, for example, requires a good understanding of technological aspects of the problem as well as of the behavior patterns of the user, land-use regulations, environmental requirements, pricing policies, and so on.

Moreover, precision is stressed – precision in describing interrelationships among factors involved in a scientific phenomenon and precision in predicting its behavior. This, coupled with increasing complexity in the problems we face, leads to the recognition that a great deal of uncertainty and variability are inevitably present in problem formulation, and one of the mathematical tools that is effective in dealing with them is probability and statistics.

Probabilistic ideas are used in a wide variety of scientific investigations involving randomness. Randomness is an empirical phenomenon characterized by the property that the quantities in which we are interested do not have a predictable outcome under a given set of circumstances, but instead there is a statistical regularity associated with different possible outcomes. Loosely speaking, statistical regularity means that, in observing outcomes of an experiment a large number of times (say n), the ratio m/n, where m is the number of observed occurrences of a specific outcome, tends to a unique limit as n becomes large. For example, the outcome of flipping a coin is not predictable but there is statistical regularity in that the ratio m/n approaches $\frac{1}{2}$ for either

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heads or tails. Random phenomena in scientific areas abound: noise in radio signals, intensity of wind gusts, mechanical vibration due to atmospheric disturbances, Brownian motion of particles in a liquid, number of telephone calls made by a given population, length of queues at a ticket counter, choice of transportation modes by a group of individuals, and countless others. It is not inaccurate to say that randomness is present in any realistic conceptual model of a real-world phenomenon.

1.1 ORGANIZATION OF TEXT

This book is concerned with the development of basic principles in constructing probability models and the subsequent analysis of these models. As in other scientific modeling procedures, the basic cycle of this undertaking consists of a number of fundamental steps; these are schematically presented in Figure 1.1. A basic understanding of probability theory and random variables is central to the whole modeling process as they provide the required mathematical machinery with which the modeling process is carried out and consequences deduced. The step from B to C in Figure 1.1 is the induction step by which the structure of the model is formed from factual observations of the scientific phenomenon under study. Model verification and parameter estimation (E) on the basis of observed data (D) fall within the framework of statistical inference. A model

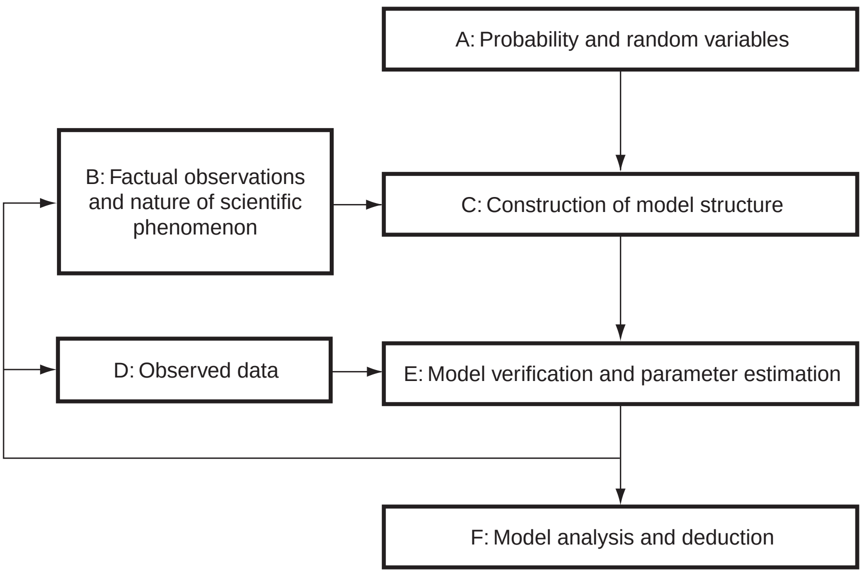

Figure 1.1 Basic cycle of probabilistic modeling and analysis

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