

Preface

Probability theory began in seventeenth century France when the two great French mathematicians, Blaise Pascal and Pierre de Fermat, corresponded over two problems from games of chance. Problems like those Pascal and Fermat solved continued to influence such early researchers as Huygens, Bernoulli, and DeMoivre in establishing a mathematical theory of probability. Today, probability theory is a well established branch of mathematics that finds applications in every area of scholarly activity from music to physics, and in daily experience from weather prediction to predicting the risks of new medical treatments.

This text is designed for an introductory probability course taken by sophomores, juniors, and seniors in mathematics, the physical and social sciences, engineering, and computer science. It presents a thorough treatment of probability ideas and techniques necessary for a firm understanding of the subject. The text can be used in a variety of course lengths, levels, and areas of emphasis.

For use in a standard one-term course, in which both discrete and continuous probability is covered, students should have taken as a prerequisite two terms of calculus, including an introduction to multiple integrals. In order to cover Chapter 11, which contains material on Markov chains, some knowledge of matrix theory is necessary.

The text can also be used in a discrete probability course. The material has been organized in such a way that the discrete and continuous probability discussions are presented in a separate, but parallel, manner. This organization dispels an overly rigorous or formal view of probability and offers some strong pedagogical value in that the discrete discussions can sometimes serve to motivate the more abstract continuous probability discussions. For use in a discrete probability course, students should have taken one term of calculus as a prerequisite.

Very little computing background is assumed or necessary in order to obtain full benefits from the use of the computing material and examples in the text. All of the programs that are used in the text have been written in each of the languages TrueBASIC, Maple, and Mathematica.

This book is distributed on the Web as part of the Chance Project, which is devoted to providing materials for beginning courses in probability and statistics. The computer programs, solutions to the odd-numbered exercises, and current errata are also available at this site. Instructors may obtain all of the solutions by writing to either of the authors, at jlsnell@dartmouth.edu and cgrinst1@swarthmore.edu.

FEATURES

Level of rigor and emphasis: Probability is a wonderfully intuitive and applicable field of mathematics. We have tried not to spoil its beauty by presenting too much formal mathematics. Rather, we have tried to develop the key ideas in a somewhat leisurely style, to provide a variety of interesting applications to probability, and to show some of the nonintuitive examples that make probability such a lively subject. **Exercises:** There are over 600 exercises in the text providing plenty of opportunity for practicing skills and developing a sound understanding of the ideas. In the exercise sets are routine exercises to be done with and without the use of a computer and more theoretical exercises to improve the understanding of basic concepts. More difficult exercises are indicated by an asterisk. A solution manual for all of the exercises is available to instructors.

Historical remarks: Introductory probability is a subject in which the fundamental ideas are still closely tied to those of the founders of the subject. For this reason, there are numerous historical comments in the text, especially as they deal with the development of discrete probability.

Pedagogical use of computer programs: Probability theory makes predictions about experiments whose outcomes depend upon chance. Consequently, it lends itself beautifully to the use of computers as a mathematical tool to simulate and analyze chance experiments.

In the text the computer is utilized in several ways. First, it provides a laboratory where chance experiments can be simulated and the students can get a feeling for the variety of such experiments. This use of the computer in probability has been already beautifully illustrated by William Feller in the second edition of his famous text *An Introduction to Probability Theory and Its Applications* (New York: Wiley, 1950). In the preface, Feller wrote about his treatment of fluctuation in coin tossing: "The results are so amazing and so at variance with common intuition that even sophisticated colleagues doubted that coins actually misbehave as theory predicts. The record of a simulated experiment is therefore included."

In addition to providing a laboratory for the student, the computer is a powerful aid in understanding basic results of probability theory. For example, the graphical illustration of the approximation of the standardized binomial distributions to the normal curve is a more convincing demonstration of the Central Limit Theorem than many of the formal proofs of this fundamental result.

Finally, the computer allows the student to solve problems that do not lend themselves to closed-form formulas such as waiting times in queues. Indeed, the introduction of the computer changes the way in which we look at many problems in probability. For example, being able to calculate exact binomial probabilities for experiments up to 1000 trials changes the way we view the normal and Poisson approximations.

ACKNOWLEDGMENTS

Anyone writing a probability text today owes a great debt to William Feller, who taught us all how to make probability come alive as a subject matter. If you find an example, an application, or an exercise that you really like, it probably had its origin in Feller's classic text, *An Introduction to Probability Theory and Its Applications*.

We are indebted to many people for their help in this undertaking. The approach to Markov Chains presented in the book was developed by John Kemeny and the second author. Reese Prosser was a silent co-author for the material on continuous probability in an earlier version of this book. Mark Kernighan contributed 40 pages of comments on the earlier edition. Many of these comments were very thought provoking; in addition, they provided a student's perspective on the book. Most of the major changes in this version of the book have their genesis in these notes.

Fuxing Hou and Lee Nave provided extensive help with the typesetting and the figures. John Finn provided valuable pedagogical advice on the text and the computer programs. Karl Knaub and Jessica Sklar are responsible for the implementations of the computer programs in Mathematica and Maple. Jessica and Gang Wang assisted with the solutions.

Finally, we thank the American Mathematical Society, and in particular Sergei Gelfand and John Ewing, for their interest in this book; their help in its production; and their willingness to make the work freely redistributable.