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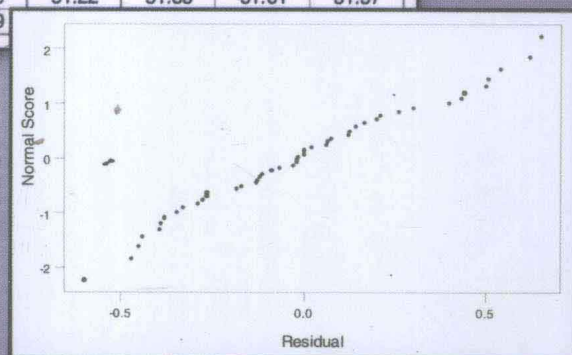
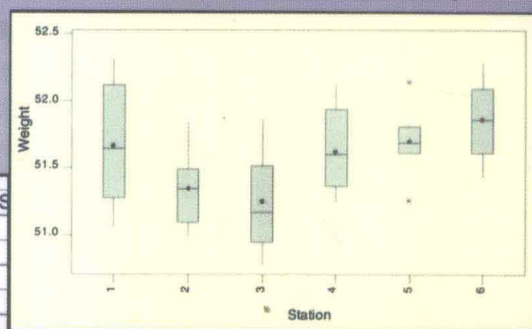
# STATISTICS *and* DATA ANALYSIS *from Elementary to Intermediate*

## 统计和数据分析 从基础到中级

- Ajit C. Tamhane  
□ Dorothy D. Dunlop  
□ 房祥忠 李东风 丁卉芬 改编

原著

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从基础到中级

Ajit C. Tamhane

原著

Dorothy D. Dunlop

*Northwestern University*

房祥忠 李东风 丁卉芬 改编

北京大学



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2005年5月

## 改编者的话

这是一本优秀的统计学教科书或参考书，主要有以下特色：

1. 概率论回顾。本书第二章为那些学习过概率论课程的读者提供了综合性回顾，以便于读者进一步学习本书。同时，这一章可以作为概率论的简要教程。

2. 收集数据。许多数据分析教材忽略了收集数据的重要性而匆忙去讲解数据分析技术。然而，如果数据收集出现偏差，则没有一种数据分析技术能够给出有效的结果。本书关于数据收集的内容包括抽样调查和试验设计，为学生进行具体的数据分析打下了扎实的基础。

3. 实际数据的广泛应用。本书通过基于实际数据的例子和练习说明统计方法和技术在各个学科中的广泛应用。数据来源包括 The New England Journal of Medicine, The American Statistician, Technometrics, US News and World Report, Science, Industrial Quality Control, European Bulletin of Cognitive Psychology 等等。为了给读者提供最大方便，这些数据文件由三种方式保存，包括 ASCII, Minitab 和 Excel 文件类型。读者可以登录高等理工教学资源网 <http://www.hep-st.com.cn> 根据书号或书名查询本书并下载这些数据资源。

4. 计算机输出的解释。计算机对现代统计分析是不可缺少的，它不仅能输入输出大量数据，而且能够快速和交互式地描绘带有信息的图表。书中多数图表和统计值来源于 Minitab 的输出结果，另外一些由 SAS 和 SYSTAT 得到。这些内容能够指导学生学习如何解释这些输出。

5. 基于数据的例子和练习。本书在每一章的末尾都按节给出基于数据的例子和练习。练习要求学生基于给出的数据利用在那一节学到的方法来回答提出的问题。许多练习通过几个步骤指导学生，每一步强调分析的不同方面。这些能够督促学生认真地思考和解释分析结果而不仅仅是计算数字。

6. 附加练习。在每一章的末尾都带有附加练习，包括简单的数学证明及一些需要综合不同章节的内容才能解决的数据分析问题。许多这样的附加练习是正文内容的扩充，是为研究生和有能力的本科生而设计的。

7. 概括总结表。概率分布、置信区间和假设检验方法被总结在一个表中便于参考和回顾，如表 7.1—7.5。

8. 广阔的覆盖面。本书具有较大的覆盖面，从初等统计学到比较高级的统计技术。对于那些利用统计技术的人士来说，本书是一本非常好的参考书，书中标有“\*”的章节可供读者选读。

在本书的改编过程中，我们完全保留了原书的框架结构，并删减了有一定难度的个别内容，一是由于课时限制，国内教学安排中通常不涉及这部分内容；二是由于保留的内容已经可以满足绝大部分读者的需要。

本书可供统计专业的本科生和研究生作为教材使用，也可供那些对统计和应用统计感兴趣的科技工作者作为参考书使用。

房祥忠 李东风 丁卉芬  
2005 年 5 月

*To Our Families*

*Meena, Shalaka, and Salil*

*and*

*John, James, and Robert*



# Preface

## Scope and Goals

This book provides a one-year calculus-based coverage of statistics and data analysis that spans from the very beginnings of the subject to intermediate level topics in mathematical statistics. We wrote this book with two main goals in mind. The first goal is to introduce the basic concepts and commonly used methods of statistics in a unified manner with sound explanations of when and how to use the methods and why they work (including mathematical derivations given in separate sections marked with asterisks). The second goal is to demonstrate diverse applications of the methods to a wide range of disciplines.

## Intended Audience

The book is primarily intended for junior and senior level undergraduates. Some of the more advanced topics in the book, especially the final chapter on the likelihood, Bayesian, and decision theory methods, can form a one-semester survey course for graduate students with good mathematical backgrounds. We have used the preliminary drafts of the book for both such undergraduate and graduate courses at Northwestern University.

## Unique Features

1. There is an extensive breadth of coverage ranging from very elementary methods to such advanced methods as logistic regression and multifactor experiments. Thus a thorough study of the book will not only prepare students to do most standard statistical analyses, but will also serve as a reference for the future.
2. The book emphasizes the applicability of statistics to a wide variety of fields (including the biomedical sciences, business, education, engineering, physical and chemical sciences, and the social sciences) by drawing examples from these fields using real data wherever possible. We hope that this cross-disciplinary approach will help students learn to be flexible and adaptive to the ever-changing demands in today's workplace, where they will often be required to deal with problems outside their fields of expertise.

3. The book covers some topics that are not included in most textbooks at this level. For example, methods of collecting data, including sample surveys and designed experiments, are discussed in an early chapter (Chapter 3). In our view, this topic should be covered before plunging into the details of data analysis. After all, how the data are collected dictates how they should be analyzed. More importantly, the method of data collection affects the quality of the data, and no amount of statistical magic can salvage a poorly designed study. This chapter discusses the important basic notions of sources of biases in data and presents randomization and blocking/matching as devices to avoid some types of biases.
4. Another topic that is not covered in most other textbooks is modern computer-intensive methods; in particular those based on the ideas of resampling and bootstrap. These are covered briefly in the chapter on nonparametric statistics (Chapter 14, Section 14.6). We subscribe to the widespread view that these methods will become increasingly important in the analysis of data as they permit a user to break the traditional shackles of strong distributional assumptions, typically normality and independence.
5. Chapter summaries are provided for a quick review of the main concepts and results. Tabular summaries of the basic formulas for standard probability distributions and tests and confidence intervals for selected parameters are given in respective chapters.
6. Each statistical method is presented and followed by one or two illustrative examples. A mathematical derivation of the method is generally given at the end of the section, and is marked with an asterisk. All advanced sections are marked with asterisks, so that the more elementary courses may skip them without disrupting the flow of the material.
7. In many cases the same examples are developed in steps in each chapter, analyzing the data in more depth as additional techniques are introduced. Some examples are carried across chapters to illustrate the applications of different methods to the same data sets.
8. We have paid particular attention to writing interesting and educational exercises. As far as possible, real data sets with sufficient background information are used. Many of the data sets are taken from the book *A Handbook of Small Data Sets* by Hand et al.<sup>1</sup>thinspace, all references to this book are abbreviated as *Small Data Sets*. Most exercises guide a student through several steps, each step addressing a different or an additional aspect of analysis. The emphasis is on urging a student to think critically and to interpret the analysis, not just calculate numbers even if they are the “right” answers.
9. Exercises for each chapter are grouped together at the end, but are categorized by chapter sections. A few drill type exercises are given at the beginning of each section, followed by more challenging ones. Advanced exercises

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<sup>1</sup>D. J. Hand, F. Daly, A. D. Lunn, K. J. McConway, and E. Ostrowski (1993), *A Handbook of Small Data Sets*, London: Chapman & Hall, 1993.

are given at the end. They typically involve simple mathematical proofs or generalizations of some results or more extensive data analyses requiring methods from different sections of the chapter. Many of these advanced exercises give students glimpses into topics beyond the scope of the present text. As such, they may be assigned to graduate students or to bright, motivated undergraduates to encourage them to pursue further studies in statistics. Answers to selected odd-numbered exercises are included at the end of the text.

10. Many exercises require the use of a computer; these exercises are marked by the symbol  $\blacksquare$ . It is recommended that some of the smaller data sets be analyzed by hand as this experience adds to the understanding of the methods. The diskette packaged in the back of the text contains data sets for all exercises.

## Supplementary Materials

The following supplementary materials are available to facilitate the use of this book.

1. **The Instructor's Solution Manual:** The manual gives detailed solutions including mathematical proofs, derivations, and graphical plots for all exercises in the book. It may be requested from the publisher upon adoption of the book.
2. **Data Disk:** The diskette packaged in the back of the text contains data sets for all exercises saved as ASCII, MINITAB, and Microsoft Excel files. Users who prefer to obtain the data files in SAS or SPSS format may download them from the web site.
3. **Web site:** A web site is set up at <http://www.prenhall.com/tamhane> where the following items will be posted as they become available: (i) errata, (ii) supplementary text material, (iii) book reviews, (iv) data files for all exercises, and (v) links to other useful sources of data sets.

### 4. Text and Student Version Software Packages:

**Statistics and Data Analysis: and SPSS 9.0 Student Version Integrated Package:** A CD-Rom containing the SPSS 9.0 for Windows Student Version and the data files from the text may be purchased as a package with the text book for a small additional charge.

**Statistics and Data Analysis: and Minitab 12.0 Student Edition Integrated Package:** A CD-Rom containing the Minitab Release 12.0 Student Edition and the data files from the text may be purchased as a package with the text book for a small additional charge.

## Background and the Tools Needed

Mathematics and probability are the two important tools needed in the study of statistics. Although calculus is used relatively in modicum in this text, a certain mathematical maturity and ability that comes with a calculus background is required. In addition, basic knowledge of matrix algebra is necessary in the chapter on multiple regression. The chapter on probability (Chapter 2) covers the essentials needed to follow the remainder of the text. This chapter is provided for review and reference purposes for those students who have had a previous course in probability. This chapter may be used as a condensed introduction to probability in a combined probability-statistics course.

Another indispensable tool required in modern statistics is a computer. It is useful not just for the tedious task of number crunching, but is equally important for plotting informative graphics in a fast and interactive manner. We assume that a student has access to a desktop computer and a statistical package or a spreadsheet package with statistical capabilities. There are many excellent statistical packages to choose from, MINITAB®, SYSTAT®, SAS®, STATGRAPHICS®, S-PLUS®, and SPSS® to name a few. The Microsoft Excel® spreadsheet package can perform many statistical tasks. It is not the purpose of this text to provide instruction in the use of any of these packages. After all, packages keep evolving, so any software instruction is likely to become obsolete even before the book is published. Fortunately, most of these packages now allow the user to perform complex statistical tasks at the click of a mouse. Also, each package has its strengths and weaknesses, and it is up to the individual instructor to choose the package that best suits the needs of his or her students. We illustrate examples using outputs from several different packages, but mainly from MINITAB, as it is one of the easiest to use.

## Possible Course Syllabi

There is more than enough material in this book for a year-long course in statistics alone (with a probability course as a prerequisite). We realize that most curricula do not have the luxury of such an extensive course. At Northwestern University, we teach a two-quarter undergraduate sequence in statistics (with a quarter-long probability course as a prerequisite), which is taken mainly by industrial engineering (IE) majors with a sprinkling of other majors. For the benefit of IE majors we focus on quality control, reliability, and some business applications primarily through examples. We are able to cover about 70% of the material in this book (excluding Chapters 2 and 15). The optional material is indicated by asterisks which we typically do not cover. Both these courses require student team projects. The project in the first course usually requires a two-group comparison based on a designed experiment or an observational study. The project in the second course requires developing a multiple regression model by using a large archival data base (e.g., marketing, salary, etc.). We also teach a one-quarter graduate course that covers multiple regression (Chapter 11), ANOVA (parts of Chapters 12 and 13), and selected mathematical statistics topics from Chapter 15.

Below we give some suggested syllabi for different undergraduate courses.

These assume that lecture hours are not used to give exams. Some instructors may choose not to omit certain indicated sections or cover them through self-reading/homeworks/problem sessions or decide to omit other sections instead. For example, instead of covering Section 4.4 on summarizing bivariate data, one may cover Section 4.5 on summarizing time-series data, or instead of covering Section 14.5 on nonparametric measures of correlation, one may cover Section 14.6 on resampling methods. Also, some instructors may want to give an elementary introduction to the topic of maximum likelihood estimation from the beginning sections of Chapter 15. In any case, we warn the instructor that the following syllabi are quite ambitious and intense in topical coverage, and not much extra material can be added to them. If anything, many of the asterisked sections may need to be omitted.

## **A One-Semester (45 one-hour lectures + 15 one-hour problem sessions) Probability-Statistics Course**

1. Chapter 1: (1 lecture)
2. Chapter 2: Sections 2.1, 2.2 (omit Section 2.2.4), 2.3, 2.4 (omit Sections 2.4.3 – 2.4.5), 2.5 (omit Sections 2.5.4, 2.5.7), 2.7 (omit Sections 2.7.3, 2.7.5, 2.7.6), 2.8 (omit Sections 2.8.3, 2.8.4), 2.9 (12 lectures)
3. Chapter 3: Sections 3.1, 3.2, 3.3 (2 lectures)
4. Chapter 4: Sections 4.1, 4.2, 4.3 (omit Section 4.3.3), 4.4 (5 lectures)
5. Chapter 5: Sections 5.1, 5.2 (3 lectures)
6. Chapter 6: Sections 6.1 (omit Section 6.1.2), 6.2, 6.3 (omit Section 6.3.4) (5 lectures)
7. Chapter 7: Sections 7.1, 7.2 (discuss Section 5.3 here) (3 lectures)
8. Chapter 8: Sections 8.1 (discuss Section 3.4 here), 8.2, 8.3 (4 lectures)
9. Chapter 9: Sections 9.1 (omit Section 9.1.3), 9.2 (omit Section 9.2.2) (2 lectures)
10. Chapter 10: Sections 10.1, 10.2, 10.3 (discuss Section 5.4 here), 10.4 (6 lectures)
11. Chapter 11: Sections 11.1, 11.2 (2 lectures)

## **A One-Quarter (30 one-hour lectures + 10 one-hour problem sessions) First Statistics Course with a Probability Prerequisite**

1. Chapter 1: (1 lecture)

2. Chapter 3: Sections 3.1, 3.2 (omit Section 3.2.2), 3.3 (2 lectures)
3. Chapter 4: Sections 4.1, 4.2, 4.3 (omit Section 4.3.3), 4.4 (5 lectures)
4. Chapter 5: Sections 5.1, 5.2 (3 lectures)
5. Chapter 6: Sections 6.1 (omit Section 6.1.2), 6.2, 6.3 (omit Section 6.3.4) (5 lectures)
6. Chapter 7: Sections 7.1, 7.2 (discuss Section 5.3 here) (3 lectures)
7. Chapter 8: Sections 8.1 (discuss Section 3.4 here), 8.2, 8.3 (4 lectures)
8. Chapter 9: Sections 9.1 (omit Section 9.1.3), 9.2 (omit Section 9.2.2) (2 lectures)
9. Chapter 10: Sections 10.1, 10.2, 10.3 (discuss Section 5.4 here) (5 lectures)

## A One-Quarter (30 one-hour lectures + 10 one-hour problem sessions) Second Statistics Course

1. Chapter 11: Sections 11.1, 11.2, 11.3, 11.4, 11.5 (discuss Section 10.4 here), 11.6 (omit Sections 11.6.4, 11.6.5), 11.7, 11.8 (10 lectures)
2. Chapter 12: Sections 12.1, 12.2 (omit Section 12.2.2), 12.4 (omit Section 12.4.5) (6 lectures)
3. Chapter 13: Sections 13.1 (omit Sections 13.1.5, 13.1.6), 13.2 (omit Section 13.2.5) (5 lectures)
4. Chapter 9: Sections 9.3, 9.4 (omit Section 9.4.3) (3 lectures)
5. Chapter 14: Sections 14.1, 14.2 (omit Section 14.2.2), 14.3 (omit Section 14.3.2), 14.4 (omit Section 14.4.2), 14.5 (omit Section 14.5.3) (6 lectures)

## Acknowledgments

First we would like to acknowledge the source of inspiration for this book, which are the following three outstanding texts: *Statistics* by David Freedman, Robert Pisani, Roger Purves and Ani Adhikari, *Introduction to the Practice of Statistics* by David Moore and George McCabe, and *Mathematical Statistics and Data Analysis* by John Rice. Their presentation of the subject is very much in line with our view of how statistics ought to be taught (albeit at increasingly higher mathematical levels). Unfortunately, these texts did not always suit our needs because of the special backgrounds of our students and the topics that we wanted to cover in our courses. We believe we are not unique in this respect. In trying to emulate these texts, we realize that we have set ourselves a very difficult but laudable goal.

We have taken data for exercises and presentation techniques from many other books. It is impossible to list them all, although we have tried to give credit in

specific cases. We apologize for any inadvertent omissions. One group whose debt can never be fully repaid is our teachers from whom we have learned a great deal, and whose ideas and thoughts permeate this book.

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Brent Logan, a PhD student in the Department of Statistics at Northwestern University, wrote the Instructor's Solution Manual and the answers to selected odd-numbered exercises given in Appendix B and found many errors in the process. All solutions were checked by Priscilla Gathoni. Several batches of students at Northwestern University toiled through early drafts of the book and gave us invaluable feedback. An early draft was also used in a course at UCLA; comments from the instructor and students in that course were very helpful. Despite all the comments and corrections that we received from many individuals, there are bound to be some residual errors for which we take full responsibility.

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Ajit C. Tamhane, Evanston, IL  
Dorothy D. Dunlop, Evanston, IL

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