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Shelemyahu Zacks

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Modern Industrial Statistics
Design and Control of Quality and Reliability

现代工业统计：质量与可靠性的设计及控制

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现代工业统计：

质量与可靠性的设计及控制

Modern Industrial Statistics: design and control of quality and reliability

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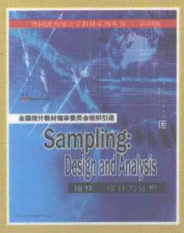

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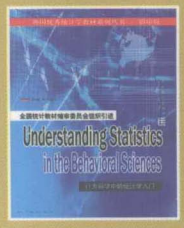

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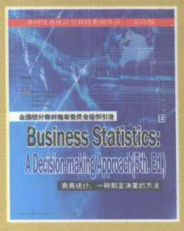

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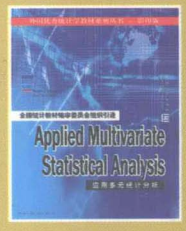

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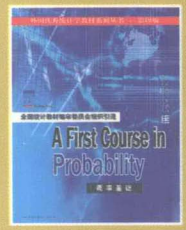

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出版说明

21世纪的竞争是人才的竞争，是全球性人才培养机制的较量。如何培养面向现代化、面向世界、面向未来的高素质的人才成为我国人才培养的当务之急。为此，教育部发出通知，倡导在全国普通高等学校中使用原版外国教材，进行双语教学，培养适应经济全球化的人才。

为了响应教育部的号召，促进统计教材的改革，培养既懂统计专业知识又具备较高英语语言能力的统计人才，全国统计教材编审委员会在国家统计局领导的大力支持下，组织引进了这套“外国优秀统计学教材”。

为了做好“外国优秀统计学教材”引进工作，全国统计教材编审委员会将其列入了“十五”规划，并成立了由海内外统计学家组成的专家委员会。在对国外统计学教材的使用情况进行了充分了解，对国内高等院校使用外国统计学教材的需求情况进行了仔细分析，并对从各种渠道推荐来的统计教材进行了认真审定的基础上，制定了引进教材书目。在确定引进教材书目的过程中，我们得到了国内外有关专家、有关院校和外国出版公司及其北京办事处的支持和帮助，在此致谢。中国人民大学统计学系的吴喜之教授不仅推荐了大量的优秀候选书目，而且校译了影印教材的翻译目录，为这套教材的及早出版作了大量的工作，我们表示衷心的谢意。

这套引进教材多数是国外再版多次、反响良好，又比较适合国内情况、易于教学的统计教材。我们希望这套引进教材的出版对促进我国统计教材的改革和高校统计学专业双语教学的发展能够起到重要的推动作用。

全国统计教材编审委员会

2002年8月28日

Foreword

A decade ago, Motorola began a journey that would shape the company's success for decades to come. The issue was survival; the challenge was quality; the solution would come from our people. We didn't have a detailed map to guide us but we set out to achieve one very large but simple goal: to improve the way we serve our customers.

Motorola's goal is virtual perfection in everything we do. Perfect quality. Perfect delivery. Perfect reliability. Perfect service. We believe that no defect is tolerable and that perfection is operationally possible. We call it Six Sigma quality.

Where quality was once measured by the number of defective parts per thousand, our Six Sigma goal translates into a defect rate of only 3.4 parts per million in each step of our processes. The goal is a visionary one but our initiative of continuous improvement reaches out for change, refinement, and even revolution in our pursuit of the highest possible quality.

Today it is not a secret that we are all awash in an overload of information, but in reality we cannot have too much relevant data. Too often companies operate in a vacuum—not knowing how their products and services truly stack up against the competition.

At Motorola we use statistical methods daily throughout all of our disciplines to synthesize an abundance of data to drive concrete actions. Only with constant monitoring and continual follow-up can you get a true picture of where you stand and a clear view of where you need to go. We use statistical data to measure both our successes and our failures. More importantly it helps us to manage our future.

How has the use of statistical methods within Motorola Six Sigma initiative, across disciplines, contributed to our growth? Over the past decade we have reduced in-process defects by over 300 fold, which has resulted in a cumulative manufacturing cost savings of over 11 billion dollars. Employee productivity (worldwide) measured in sales dollars per employee has increased three fold or an average 12.2 percent per year over the same 10 year period. Our product reliability as seen by our customer has increased between 5 and 10 times.

Each year over 6,000 Total Customer Satisfaction empowered teams are formed, representing more than 60,000 of our 138,000 employees to solve problems and drive continuous improvement. Over half of these teams are from non-manufacturing disciplines, such as finance, legal, personnel, engineering, and service, all using statistical tools to drive perfection in everything we do.

If you don't set out to achieve perfection, you probably aren't going to achieve it.

Robert W. Galvin
Chairman of the Executive Committee
Motorola, Inc.

Preface

Modern Industrial Statistics: Design and Control of Quality and Reliability provides the tools for those who drive to achieve perfection in industrial processes. Learn the concepts and methods contained in this book and you will understand what it takes to measure and improve world-class products and services.

The need for constant improvement of industrial processes, in order to achieve high quality, reliability, productivity and profitability, is well recognized. Further, management techniques, such as total quality management and business process reengineering, are insufficient in themselves to achieve the goal without the strong backing of specially tailored statistical procedures, as stated by Robert Galvin in the Foreword.

Statistical procedures designed for solving industrial problems are called Industrial Statistics. Our objective in writing this book was to provide statistics and engineering students, as well as practitioners, the concepts, applications, and practice of basic and advanced industrial statistical methods, which are designed for the control and improvement of quality and reliability.

The idea of writing a text on industrial statistics developed after several years of collaboration in industrial consulting, teaching workshops and seminars, and courses at our universities. We felt that no existing text served our needs in both content and approach so we decided to develop our notes into a text. Our aim was to make the text modern and comprehensive in terms of the techniques covered, lucid in its presentation, and practical with regard to implementation.

Features

Modern Industrial Statistics employs several unique characteristics. Among the most significant is its integration and use of the computer in solving real industrial problems.

- **Resampling techniques**, or ***bootstrapping***, which occupy a central position in the practice of statistics, have freed the researcher and the practitioner from imposing on a problem theoretical assumptions that are difficult to verify. They can also substitute complex analytical methods for assessing the properties of statistical decision and control procedures. Many regard bootstrapping methods as the inferential and decision-making tools of the 21st century.
- **Simulators**, which perform simulations, have been specially developed for the book to assess the operating characteristics of various process-control procedures such as the cycle speed of a piston in a gas turbine and the output current of an electrical circuit. These simulators are used in various parts of the book to

generate observations under specific conditions. Our book is unique in its use of the computer as a tool for analysis, design, and control.

- MINITAB is used throughout the book. This package was chosen because of its wide availability, in student or professional versions for Windows, mainframes, or UNIX platforms. Moreover, MINITAB is user friendly, interactive, and easy to teach. An appendix covering the basic features and commands of MINITAB is included.
- In addition, S-PLUS, which has become a package of choice for the more advanced user, is included as well. We furnish all the S-PLUS functions and routines needed for the book in a special appendix.
- Included in the book is a CD-ROM containing all the data sets and the programs that were specifically developed for the book. The programs are either executable files (.EXE) or MINITAB macros (.MTB) stored in subdirectories corresponding to the chapters in which they're first introduced. The S-Plus functions are provided on the CD-ROM as well. The data sets, the simulators, the executable programs, the macros, and the S-PLUS functions are all described in the appendices.
- The book is easily adaptable to other software packages. Faculty interested in using MATLAB, SAS, JMP-IN, STATGRAPHICS, EXCEL, or SPSS can read the data files into other formats by following the data library on the Duxbury Resource Center at **www.duxbury.com**

Organization and Coverage

The book is comprised of fourteen chapters, organized in two parts. Part I consists of eight chapters, emphasizing statistical thinking in industrial settings, employing data analysis, graphical techniques, and data-based simulations. Most examples in the book are from actual industrial problems, illustrating the versatility and applicability of the statistical methods. Part I includes chapters on probability models, statistical distributions, and estimation and testing of hypotheses. It contains a chapter on sampling from finite populations (needed for bootstrapping and for sampling inspection and auditing of quality), a chapter on bootstrap and nonparametric methods, and a chapter on multiple regression and categorical data analysis. Part II is devoted to six chapters covering basic and advanced methods of industrial control and improvement of quality and reliability. The Solutions Manual contains the complete solutions to all of the problems in the text.

Students taking courses in industrial statistics and using this book will need knowledge of calculus and some matrix theory (linear algebra). We developed the material for upper division undergraduates and beginning graduate students in the fields of Industrial Engineering and Statistics. Students of electrical and mechanical engineering can also benefit from the book. The text can also provide a reference to practitioners working in the areas of quality management, quality engineering, and reliability.

A two-semester course can cover a good part of the book. However, the book was designed to be flexible enough for one-semester courses and several differing course needs. Examples of how the book may be used in one-semester courses are:

Introduction to Industrial Statistics: Chapters 1, 2, 3, 4, 6, 7

Sampling Plans and Reliability: Chapters 4, 5, 6, 7, 9, 14

Statistical Process Control: Chapters 1, 4, 6, 7, 10, 11

Statistics for Quality Design and Improvement: Chapters 4, 6, 8, 10, 12, 13

Advanced Industrial Statistics: Chapters 7, 8, 9, 11, 12, 13, 14.

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The authors wish to thank their families for their encouragement, the administration of Binghamton University for its support, and the various industries at which they worked or consulted for the opportunity to solve industrial problems. The examples presented in the text have many people behind them and it is impossible to acknowledge all contributors. Among those contributors we should, however, mention several key individuals: Mr. Richard Buetow from Motorola, Mr. Haim Rosen, Mr. Meir Sperling and Mr. Yakov Bantay from Tadiran Telecommunications and Professor Tom Kelley from Binghamton University. We thank the following reviewers for their thoughtful feedback to earlier drafts of the manuscript: James A. Alloway, E.M.S.Q. Associates; Robert L. Armacost, University of Central Florida; Michael Martin, Australian National University, Canberra; P. Simon Pulat, University of Oklahoma; and Derek Rollins, Iowa State University. We wish to thank the editor, Mr. Curt Hinrichs; the editorial staff and accuracy checkers for their excellent suggestions, corrections, and editorial work; and for production editing, Timothy Wardell at Brooks/Cole. Special thanks are due to Mrs. Marge Pratt for her excellent typing of the text.

S. Zacks
Binghamton, NY

R.S. Kenett
Raanana, Israel

To Sima, Dolav, Ariel, Dror and Yoed with whom I share everything
Ron S. Kenett

To my wife Hanna, our sons Yuval and David and their families with love
Shelemyahu Zacks

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目录

第一篇　统计思维和分析的原则　1

第1章　统计方法在现代工业中的作用　2
1.1　工业的不同功能区域　2
1.2　质量-生产率悖论　4
1.3　救火　6
1.4　产品检验　8
1.5　过程控制　9
1.6　用设计确保质量　10
1.7　本章要点　12
1.8　练习　13

第2章　了解变异性　14
2.1　随机现象和观测值的结构　14
2.2　测量的准确度和精度　18
2.3　总体和样本　18
2.3.1　从一个有限总体中抽取一个随机样本　19
2.3.2　从一个无限总体中抽取一个随机样本　20
2.4　样本数据的描述性分析　21
2.4.1　离散随机变量的频率分布　21
2.4.2　连续随机变量的频率分布　25
2.4.3　有序样本的统计量　28
2.4.4　位置和离散程度的统计量　30
2.5　预测区间　34
2.6　其他探索性数据分析的方法　35
2.6.1　箱线图　35

2.6.2 分位数图 36
2.6.3 茎叶图 37
2.6.4 位置和离散程度的稳健统计量 38
2.7 本章要点 40
2.8 练习 41

第3章 多维的变异性 44
3.1 图形展示和分析 44
3.1.1 散点图 44
3.1.2 多重箱图 47
3.2 动态图 49
3.2.1 三维旋转图 49
3.2.2 梳理、编码和变换 49
3.3 多维的频率分布 50
3.3.1 二维联合频率分布 51
3.3.2 条件分布 54
3.4 相关和回归分析 55
3.4.1 协方差和相关 55
3.4.2 根据数据拟合简单回归直线 58
3.4.2.1 最小二乘法 58
3.4.2.2 回归和预测值区间 62
3.4.2.3 相关和回归的稳健方法 63
3.5 列联表 68
3.5.1 列联表的结构 68
3.5.2 列联表的关联指数 72
3.5.2.1 两区间尺度变量 72
3.5.2.2 分类变量的关联指数 73
3.6 本章要点 77
3.7 练习 78

第4章 概率和分布函数的基本模型 80
4.1 基础概率 80
4.1.1 事件和样本空间：随机测度的正规表述 80
4.1.2 事件运算的基本规则：并与交 82
4.1.3 事件的概率 84
4.1.4 随机抽样的概率函数 86
4.1.5 事件的条件概率和独立性 88
4.1.6 贝叶斯公式及其应用 90

4.2 随机变量及其分布 92
4.2.1 离散分布和连续分布 93
4.2.1.1 离散型随机变量 93
4.2.1.2 连续型随机变量 94
4.2.2 分布的期望和矩 97
4.2.3 标准差、分位数、偏度和峰度 99
4.2.4 矩母函数 102
4.3 离散分布族 103
4.3.1 二项分布 103
4.3.2 超几何分布 105
4.3.3 泊松分布 109
4.3.4 几何分布和负二项分布 110
4.4 连续分布 113
4.4.1 在区间 (a, b)(a<b)上的均匀分布 113
4.4.2 正态分布和对数正态分布 114
4.4.2.1 正态分布 114
4.4.2.2 对数正态分布 119
4.4.3 指数分布 120
4.4.4 伽玛分布和威布尔分布 122
4.4.5 贝塔分布 125
4.5 联合、边际和条件分布 126
4.5.1 联合分布和边际分布 126
4.5.2 协方差和相关 129
4.5.3 条件分布 131
4.6 一些多维分布 134
4.6.1 多项分布 134
4.6.2 多维超几何分布 136
4.6.3 二维正态分布 137
4.7 顺序统计量的分布 139
4.8 随机变量的线性组合 141
4.9 大样本逼近 146
4.9.1 大数法则 146
4.9.2 中心极限定理 147
4.9.3 一些正态近似 148
4.10 正态样本统计量的其他分布 149
4.10.1 样本方差的分布 149
4.10.2 学生 t 统计量 151
4.10.3 方差比率的分布 152

4.11 本章要点 153
4.12 练习 154

第5章 有限总体量的抽样估计 160
5.1 抽样和估计问题 160
5.1.1 基本定义 160
5.1.2 总体量及其抽样分布的样本估计值 161
5.2 根据简单随机样本进行估计 165
5.2.1 在放回随机抽样下 $\overline{X}_n$ 和 S^2_n 的性质 166
5.2.2 在不放回随机抽样下 $\overline{X}_n$ 和 S^2_n 的性质 168
5.3 根据分层不放回随机抽样估计均值 172
5.4 按比例分配和最优分配 173
5.5 在协方差已知下的预测模型 177
5.6 本章要点 180
5.7 练习 182

第6章 参数统计推断 183
6.1 估计量的抽样特征 183
6.2 点估计的一些方法 185
6.2.1 矩方程估计量 186
6.2.2 最小二乘方法 187
6.2.3 极大似然估计量 189
6.3 样本估计值与指定标准的比较—检验统计假设 191
6.3.1 基本概念 191
6.3.2 一些通常的单样本假设检验 195
6.4 置信区间 202
6.4.1 当 σ 已知时，μ 的置信区间 203
6.4.2 当 σ 未知时，μ 的置信区间 203
6.4.3 σ^2 的置信区间 203
6.4.4 p 的置信区间 204
6.5 容差区间 206
6.5.1 正态分布的容差区间 206
6.5.2 不依赖于分布的容差区间 209
6.6 根据概率图检验正态性 210
6.7 拟合优度检验 214
6.7.1 卡方检验（大样本） 214
6.7.2 柯尔莫哥罗夫-斯米尔诺夫检验 216
6.8 贝叶斯决策方法 218

6.8.1 先验分布和后验分布 219
6.8.2 贝叶斯检验和估计 222
6.8.2.1 贝叶斯检验 222
6.8.2.2 贝叶斯估计 225
6.8.3 真实参数的可信区间 225
6.9 本章要点 227
6.10 练习 227

第7章 不依赖于分布的推断：计算机密集方法 231
7.1 来自参照分布的随机抽样 231
7.2 自助抽样 234
7.2.1 自助法 234
7.2.2 自助法的审视 235
7.2.3 自助法的驾驭 236
7.3 假设的自助检验 236
7.3.1 均值的自助检验和置信区间 237
7.3.2 均值的学生检验 237
7.3.3 两均值差异的学生检验 239
7.3.4 方差的自助检验和置信区间 240
7.3.5 几个样本统计量的比较 241
7.3.5.1 几个样本方差的比较 241
7.3.5.2 几个均值的比较：单向方差分析 242
7.4 自助容差区间 244
7.4.1 贝努里样本的自助容差区间 244
7.4.2 连续变量的容差区间 246
7.5 非参数检验 247
7.5.1 符号检验 247
7.5.2 随机化检验 249
7.5.3 威尔科克森符号秩检验 251
7.6 本章所用的MINITAB宏和可执行文件 252
7.7 本章要点 253
7.8 练习 254

第8章 多重线性回归和方差分析 256
8.1 对两变量的回归 257
8.2 偏回归和偏相关 261
8.3 多重线性回归 263
8.4 偏F检验和序贯平方和 267

8.5 模型构造：逐步回归 269
8.6 回归诊断 272
8.7 定量反应分析：罗吉斯蒂克回归 275
8.8 方差分析：均值的比较 276
8.8.1 统计模型 276
8.8.2 单向方差分析（ANOVA） 277
8.9 联合置信区间：多重比较 281
8.10 分类数据分析 283
8.10.1 二项试验的比较 284
8.10.2 列联表的卡方检验 285
8.11 本章要点 287
8.12 练习 288

第二篇 工业统计的方法 291

第9章 产品检验的抽样计划 292
9.1 一般讨论 292
9.2 属性变量的单阶段抽样方案 294
9.3 抽样方案的近似确定 297
9.4 属性变量的双重抽样方案. 299
9.5 序贯抽样 303
9.6 变量的接受抽样方案 307
9.7 批量的纠正性检验 310
9.8 国家标准和国际标准 312
9.9 属性变量的跳跃性分批抽样方案 314
9.9.1 ISO 2859 跳跃性分批抽样方法 314
9.10 德明检验标准 317
9.11 接受抽样的公布表 318
9.12 本章要点 319
9.13 练习 320

第10章 统计过程控制的基本手段和原则 322
10.1 统计过程控制的基本概念 322
10.2 通过控制图操纵一个过程 332
10.3 设定控制图：过程性能研究 336
10.4 过程性能指数 338
10.5 过程控制和过程改进的七种手段 341
10.6 帕累托图的统计分析 345

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