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INTRODUCTORY STATISTICS AND PROBABILITY FOR ENGINEERING, SCIENCE, AND TECHNOLOGY

ELWOOD G. KIRKPATRICK
School of Industrial Engineering
Purdue University

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INTRODUCTORY STATISTICS AND PROBABILITY FOR ENGINEERING, SCIENCE, AND TECHNOLOGY

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To Eileen and Tom

PREFACE

This textbook is an introduction to some of the basic concepts and techniques of statistical analysis. It is directed primarily at the undergraduate technology and engineering student who has completed one introductory course in calculus. No previous background in either probability or statistics is assumed.

The book can be used for a one or two semester course depending on the emphasis and time devoted to end-chapter applications problems. For a two semester sequence, it is presumed that the instructor will complement this book with a formal design of experiments text of his choice. This book has been designed to satisfy the need for an introductory statistics text oriented to engineering applications, a text that is concise, readable by the average student, of moderate length, and not too mathematical. Two basic objectives of the text are: (1) to select and construct subject matter requirements that are attainable by the average student, and (2) to identify and structure topics to introduce the subject to a student who is meeting statistics for the first time.

To satisfy these objectives at this level, it is necessary not only to acquaint the reader with statistical methods but also to indicate the mathematics required to establish the methods on a sound basis. Thus, the presentation is essentially a compromise between a book that gives only statistical

techniques and a book that attempts complete mathematical rigor. Some mathematical foundations are given to structure the subject and to stimulate the interested student to pursue specialized and more advanced courses in statistics. A nominal sacrifice of simplicity has been made at the beginning in order to introduce concepts that are fundamental to the development of the subject. For example, the distribution function and characteristic function are introduced in elementary fashion early in Chaps. 3 and 4. However, emphasis throughout the text is primarily on language, method, and applications problems.

An observation made by the author on many occasions is that junior and senior engineering students, who have had one or two statistics courses, frequently demonstrate a remarkable lack of statistical facility in other courses that use statistical tools for quantitative evaluations. One conjecture as to this puzzling end result is that the mathematics of applied statistics is not too difficult, but the amount of time that is required to pursue topics in depth leaves little time for applications and analysis practice. Operating from this assumption, this text is designed to save time wherever possible. Simple functions are used to illustrate concepts. For example, the uniform distribution function is used frequently in Chaps. 3 and 4 to illustrate obtaining distribution moments using either expected value or characteristic function methods. Other simple linear functions are used in examples, exercises, and problems. This is also the reason for an early presentation of the discrete random variable models.

Simple and direct exercises are given regularly throughout each chapter (more rigorous and applied problems are separated into the end-chapter problem assignments). Extensive use is made of graphical explanations and summaries, particularly for the problems of Chaps. 5, 7, 8, and 10. The purpose throughout is to take cognizance of the fact that technology and engineering students simply do not have the time to study statistics in a career fashion.

The author also feels that another important item related to the aforementioned student difficulty is the verbal factor. A first chore for the average reader is to sort the verbiage and condense it to a meaningful structure for himself—a task usually requiring extensive help by the instructor. To simplify this chore, use is made of discussion–paragraph asides blocked out separately from the main paragraphs. Generally, the main paragraphs read continuously and the discussion paragraphs contribute support material—intuitive explanations, of–interest–only derivations, additional argument, detail, exceptions, special cases, and so forth. Student difficulties seem to stem from too much material presented too rapidly and coincidentally. The pedagogical approach throughout this text is that of separation of material. The discussion paragraph asides separate out two types of supplementary material: (1) additional

intuitive explanations and aids for the below–average student, and (2) mathematical foundations to interest the above–average student.

In an introductory textbook, the selection of topics, their order of presentation, and extent of coverage are to some degree subjective decisions. There is no one correct sequence and there are a variety of effective teaching combinations. To meet objectives, frequent tradeoffs were made in developing the text, and sophisticated detail was necessarily omitted in some cases. Only elementary probability concepts are presented for the limited purpose of introducing the general statistical topics. A combinatorial rather than a set–theory approach is used. It is felt that the latter view is too abstract for an introductory text, and that the combinatorial approach is more adaptable to an intuitive counting of events and occurrences. Discrete distribution models are introduced early (Chap. 4) to afford simple examples of obtaining distribution moments and also as a means of introducing probabilities of events of the form $X \leq b$ and thereby gradually leading to the use of tables for making probability statements. The topic of sampling inspection (without analysis) is introduced early to obtain practical applications and examples for the binomial and Poisson models. The topics receiving the most coverage are descriptive statistics and hypothesis testing. The latter topic is perhaps the most important single topic in an introductory statistics textbook as it is fundamental to all advanced statistical topics.

The principal quality control topics (Chap. 8) follow immediately the presentation of hypothesis testing (Chap. 7) to further illustrate tests of hypotheses. Since engineering problems often require a presentation of data showing the observed relationship between variables, a separate chapter on curve fitting (Chap. 9) has been included. This treatment, without any of the assumptions required for regression, makes for a less abrupt entry into the regression topic. The chapter on regression that follows also lends itself to a gradual and more meaningful introduction to analysis of variance.

I am grateful to Mrs. Jong-Ping Hsu for her careful review of the manuscript, and to Dr. J. H. Mize, Oklahoma State University, for his review and many helpful suggestions. I am especially grateful to Mr. Kenneth Hopping for his thorough effort on the tedious job of proofreading.

I am indebted to the Literary Executor of the late Sir Ronald A. Fisher, F.R.S., to Dr. Frank Yates, F.R.S., and to Oliver and Boyd, Edinburgh, for permission to reprint Tables of the chi square, *t*–, and *F*–distributions (Appendixes E, F, and G) from their book *Statistical Tables for Biological, Agricultural and Medical Research;* to Dr. Frederick E. Croxton for permission to reprint the normal distribution Table (Appendix D) from his book *Elementary Statistics with Applications in Medicine and the Biological Sciences*, Dover Publications, Inc., 1959; to the *Annals of Mathematical Statistics* and Professors C. L. Ferris, F. E. Grubbs, and C. L. Weaver for permission to

reproduce their Operating Characteristic Curves for Significance Tests (Chap. 7); to Dr. George W. Snedecor for permission to reprint a random numbers Table (Appendix I) from his book *Everyday Statistics;* to Professors A. H. Bowker and G. J. Lieberman and the Stanford University Press for permission to reproduce the hypergeometric table (Appendix C) from their book *Tables of the Hypergeometric Probability Distribution*; and to the American Society for Testing Materials for permission to reproduce Table B.2 (Appendix H) from their *A. S. T. M. Manual on Quality Control of Materials.*

West Lafayette, Indiana ELWOOD G. KIRKPATRICK

CONTENTS

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INTRODUCTORY STATISTICS AND PROBABILITY FOR ENGINEERING, SCIENCE, AND TECHNOLOGY

INTRODUCTION

Statistics is concerned with methods for the collection, analysis, and interpretation of quantitative data in such a way that conclusions based on the data can be objectively evaluated in terms of probability statements. The collection of data and computation of various indices such as averages and percentages is called descriptive statistics. *Systematic drawing of conclusions from the data is called* statistical inference.

1.1 Statistical Inference

The deductive method (or proof) makes inferences or conclusions from accepted principles. On the other hand, the inductive method draws conclusions from several known cases, reasoning from the particular to the general. The technology of deduction is mathematics, while that of induction is statistics. An old science, which has already developed a number of basic principles, can use mathematics to deduce more information from these principles. A young science depends on statistics to develop the basic principles. All sciences use statistical tools for reaching conclusions from experimental data.

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Although inductive reasoning—going from the particular to the general—can lead to numerous difficulties, it is still possible to be precise about it in terms of the risk involved in making such an inference. The topic of statistical inference may be regarded in this light. The effort is not aimed at making statements each of which is guaranteed to be 100% correct, but rather at making inferences that have a certain probability of being correct.

1.2 Statistical Investigation

The important phases of a statistical investigation are:

1. Definition of the problem.
2. Design of the experiment.
3. Data collection.
4. Data reduction and computations.
5. Analysis.

A formulation or *definition* of the problem includes: (1) statement of the problem, (2) choice of dependent variable (or variables) to be studied, and (3)

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