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Statistical Intervals: A Guide for Practitioners and Researchers (2nd Edition)

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In certain situations, a researcher may need interval rather than point estimates for the parameter of interest (e.g., mean, standard deviation, proportion, or regression weights). This scenario often arises in industrial applications of statistics, such as reliability engineering, where intervals are needed for prediction of a condition, such as product lifetime failure. Traditional point estimate procedures are well covered in textbooks, while interval estimates are only touched upon mostly as an additional inference procedure. Therefore, researchers who mainly rely on statistical intervals may find the materials in applied statistics books inadequate. *Statistical Intervals: A Guide for Practitioners and Researchers (2nd Edition)* attempts to fill this gap using the statistical package R.

The book has 18 chapters and ten technical appendices. The first ten chapters present less mathematically and computationally sophisticated methods for obtaining statistical intervals, followed by a chapter of case studies that demonstrates the application of those methods. Chapters 12–17 (which are new to the second edition of the book) present more advanced materials, followed by the last chapter on case studies. Each chapter ends with annotated bibliographic notes. There are no exercises, but the case study chapters can be used to practice the methods if the reader intends to. The statistical language R is used to demonstrate calculation and computation. The authors have bundled the necessary functions in the package **StatInt**, which can be downloaded from the book's companion website (which also hosts the data sets.)

The authors introduce the concepts of uncertainty, inference, and prediction in Chapter 1, *Introduction, Basic Concepts, and Assumptions*. Throughout, "uncertainty" and how it is expressed through statistical intervals is elaborated. Different types of intervals covered in the book (confidence intervals, tolerance intervals, and prediction intervals) are discussed in this chapter. Furthermore, the authors distinguish between enumerative and analytic studies (see Deming 1975 for an original discussion of these concepts). In this chapter, the authors present foundational concepts such as assumptions underlying the data, sampling methods, study planning, and interpretation of interval estimates. Chapter 2, *Overview* *of Different Types of Statistical Intervals*, further presents the important topics of different types of statistical intervals, one-sided and two-sided statistical intervals, how to choose an appropriate statistical interval, simultaneous statistical intervals, sample size considerations, and the selection of the confidence level. Once the fundamental concepts are introduced in the first two chapters, the authors present methods for the calculation of statistical intervals.

In Chapter , *Constructing Statistical Intervals Assuming a Normal Distribution Using Simple Tabulations*, the authors discuss the construction of confidence, prediction, and tolerance intervals for normally distributed data using plug-in standard normal tables. Chapter 4, *Methods for Calculating Statistical Intervals for a Normal Distribution*, presents calculation methods for constructing different types of statistical intervals for the mean, standard deviation, and proportions. The use of R begins in this chapter. Chapter 5, *Distribution-Free Statistical Intervals*, discusses a scenario where the distribution of the data is unknown. The main focus in this chapter is on order statistics and quantiles (median, minimum, maximum). This chapter uses tabular, graphical, and computational methods to obtain upper and lower bounds for quantiles and proportions.

In Chapter 6, *Statistical Intervals for a Binomial Distribution*, the authors present how to construct statistical intervals for proportions or percentages. This chapter clearly shows the role of one-sided statistical intervals in applications where the purpose of the study is to meet a lower or upper bound estimate. Both approximate (Wald, Agresti-Coull, Jeffreys methods) and conservative statistical intervals are demonstrated and compared. Statistical intervals for count data are presented in Chapter 7, *Statistical Intervals for a Poisson Distribution*, where again conservative and approximate methods are presented with various examples for one-sided and two-sided bounds.

Determining study sample size becomes a consideration where obtaining a sample is costly. Sample size requirement calculation for a certain confidence level is discussed in Chapter 8, *Sample Size Requirements for Confidence Intervals on Distribution Parameters.* This chapter can be regarded as an extension to chapters two and three where the fundamental concepts of statistical intervals and study planning were introduced. Graphical, tabular, and computational methods are used for calculating an optimal sample size for different parameters of the normal and the Poisson distributions. Optimal sample size calculation is further discussed in Chapter 9, *Sample Size Requirements for Tolerance Intervals, Tolerance Bounds, and Related Demonstration Tests*; the chapter presents intervals with and without assuming a (normal) distribution for the data. Standard graphical and tabular methods are used alongside computation methods (using R) with various examples from engineering fields. Sample size calculation is further discussed in Chapter 10, *Sample Size Requirements for Prediction Intervals*, where the scenario shifts from an existing population to a future population. This short chapter opens with a discussion on the sources of variation when sample size is being calculated for a future population and proceeds to sample size requirements for a future population mean, proportion, and standard deviation (both with and without assuming a normal distribution).

Extensive case study examples for all the methods presented in the first ten chapters are presented in Chapter 11, *Basic Case Studies.* As the title of the chapter suggests, more advanced methods of statistical interval computation are presented in the next six chapters of the book, followed by a chapter on advanced case studies.

The more advanced and computationally intensive statistical methods in the rest of the book include bootstrap and Bayesian methods in parameter estimation. The authors demonstrate the application of computer intensive methods in constructing different types of statistical intervals. Therefore, the R language gains a more pivotal role in these chapters.

Chapter 12, *Likelihood-Based Statistical Intervals*, discusses the application of maximum likelihood (ML) for more complicated data, such as when the data is censored or truncated. After introducing the concepts of and motivation for ML methods, the authors present methods and examples for estimating a single parameter and how to construct statistical intervals for that parameter. In addition, ML methods for location-scale, log-location-scale, and Weibull distributions are presented. Profile likelihood confidence intervals are also introduced when there is a vector of parameters. Finally, Wald approximations based on ML estimates are introduced for mean, standard deviation, and correlation. Tolerance and prediction intervals are briefly presented.

Bootstrap sampling methods for smaller sample sizes of continuous data are presented in Chapter 13, *Nonparametric Bootstrap Statistical Intervals*. The authors present the motivation for the use of Monte Carlo simulation for nonparametric statistics, practical considerations in resampling, methods of computation (basic, bias-corrected, bias-corrected accelerated, bootstrap-t), and the assumptions for the use of bootstrap methods. Distribution-based bootstrap methods to estimate statistical intervals are presented in Chapter 14, *Parametric Bootstrap and Other Simulation-Based Statistical Intervals*, where in addition to bootstrap, the authors present pivotal quantity simulation for parametric tolerance and prediction intervals, and random-weight bootstrap methods. Like in the previous chapter, the authors clarify the context for the use of distribution-based bootstrap methods.

The Bayesian approach to the construction of statistical intervals is presented in Chapter 15, *Introduction to Bayesian Statistical Intervals*. Traditional methods of using conjugate priors, Monte Carlo simulation, and Markov chain Monte Carlo (MCMC) methods are introduced for obtaining credible, tolerance, and prediction intervals. The authors present the motivation for the Bayesian approach, Bayes concepts, an example using Weibull distribution, a discussion on prior distributions and how to choose them, MCMC simulation for Bayesian inference, and one-sided and two-sided tolerance and prediction interval estimates based on the Bayesian approach. This chapter can be mainly viewed as a conceptual and theoretical introduction to the Bayesian framework for estimating statistical intervals. In the related Chapter 16, *Bayesian Statistical Intervals for the Binomial, Poisson, and Normal Distributions*, the authors present concrete examples where statistical intervals for the distribution parameters are estimated using a Bayesian approach. The readers can see more R code used in this chapter. Chapter 17, *Statistical Intervals for Bayesian Hierarchical Models*, presents scenarios where the data have multilevel structure. After introducing hierarchical and random-effects models, the authors present models and examples for normal, binomial, Poisson, and repeated measures data.

The advanced section ends with Chapter 18, *Advanced Case Studies*, where numerous extended examples are presented to demonstrate the application of the methods presented in chapters twelve to seventeen. Similar to other examples and case studies in the book, the problems presented in this chapter reflect the application of statistical intervals in industrial contexts.

Finally, the technical appendices at the end of the book provide the interested reader with necessary theory that underpins the methods introduced in the text.

Inference using statistical intervals is an understated topic in traditional applied statistics books and programs. In fact, the topic is often visited only in a few pages of the inference section of a method, and rarely used in interpretation of the results. However, with more researchers and journals demanding information other than point estimates, statistical intervals are gaining more acceptance among researchers and practitioners.

Statistical Intervals: A Guide for Practitioners and Researchers (2nd Edition) holds a wealth of practical knowledge on different types of statistical intervals using traditional and modern computation methods. The book embodies the authors' extensive experience and rigorous attention to the selection of the most common statistical intervals used and needed in industrial settings for practitioners and researchers. Thoroughness is the greatest feature of this book, where most types of estimates and distributions are presented, with clear examples and often R code to calculate them. The examples in the book are often encountered in industrial fields where the main objectives of the study are to obtain interval estimates and minimum sample size. These two topics are extensively discussed in the book and reinforced with practical examples. The authors provide annotated bibliographic notes at the end of each chapter so that the interested readers can gain deeper understanding of the topics. In addition, the technical appendices provide the theoretical insight into most methods presented in the book.

Although the early chapters do not need much computation, the more advanced chapters that present simulation, bootstrapping, and Bayesian approach would benefit if more sample R code were included to demonstrate how those examples in the book were solved and how to use R to solve further problems.

Overall, *Statistical Intervals: A Guide for Practitioners and Researchers (2nd Edition)* is a unique, modern, and practical reference for practitioners and researchers in manufacturing and engineering. The structure of the text, with so many subsections, clearly shows its goal as mainly providing a handbook for industrial statisticians who need practical guidance for appropriate statistical intervals. The book achieves its purpose rigorously and thoroughly.

References

Deming WE (1975). "On Probability as a Basis for Action." *The American Statistician*, **29**(4), 146–152. doi:10.1080/00031305.1975.10477402.

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