approach would provide a natural way to properly account for uncertainty in the fixed effects in mixed models, due to the uncertainty in the parameters of the random-effects covariance matrix, and in prediction in spatial models due to the uncertainty in the estimation of the variogram parameters.

Overall, *Contemporary Statistical Models for the Plant and Soil Sciences* is a solid text with many real-world examples/applications. It could be used for a second or third methods course for nonstatistics graduate students, or as a text for the second semester of a two-semester methods sequence for statistics masters students. The authors should be commended for providing a comprehensive and modern methods textbook for researchers in the agricultural sciences.

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**Multivariate Dispersion, Central Regions and Depth: The Lift Zonoid Approach.**

Karl MOSLER. New York: Springer-Verlag, 2002. ISBN: 0-387-95412-0. x + 291 pp. $69.95 (P).

This book introduces lift zonoids and their applications to statistics, probability, and economics. The author and his collaborators have published extensively in this area of research, and their theory has been integrated into this book. Overall, the book is well-written, and starts with a good overview of the contents and goals.

The book presents a number of concepts, including the zonoid, that likely will be new to many statisticians (as they were to me). The lift zonoid is a representation of a multivariate probability distribution (more generally, a positive measure in Euclidean space). The volume of a lift zonoid reflects the dispersion of the distribution.

Theorem 2.17 has a characterization (or alternative definition) of the lift zonoid. For a univariate cumulative distribution function (cdf) $F$ with finite expectation, the lift zonoid is the convex hull of the points $(0, 0)$, $\left( \int_0^\infty dF(x), \int_0^y x \, dF(x) \right)$, $y \in \mathbb{R}$, and $\left( \int_0^\infty x \, dF(x), \int_0^y x \, dF(x) \right)$, $y \in \mathbb{R}$. With this characterization, I was able to duplicate the figures in Figures 1.4–1.6 (pp. 11–12). For an empirical version of the lift zonoid with data, replace $F$ with an empirical distribution $F_n$.

The definition of a lift zonoid for a multivariate cdf $F$ has several equivalent forms, one of which involves a convex hull. The lift zonoid is partly motivated as a multivariate extension of the Lorenz curve, which is used by economists for displaying income distributions. In the univariate case, the boundaries of the convex hull are the Lorenz and reverse Lorenz curves.

The main statistical applications are zonoid trimmed region (an example of a multivariate central region), the zonoid depth (a notion of multivariate data depth), and the mean hyperplane depth (a measure of combinatorial dispersion useful for two-sample comparisons). A data depth is a multivariate version of a quantile for quantifying whether a data point lies near the center or the extreme or somewhere in between, and a set of multivariate central regions can be useful for detecting outliers in data. The set of $a$-trimmed regions for $0 \leq a \leq 1$ is a family of nested regions, with $a = 1$ corresponding to a set with one point (the mean) and $a = 0$ corresponding to the entire (Euclidean) space.

With the data depth, one can do inference, such as two-sample tests for scale and for location/scale. This is the topic of Chapter 5, written by Rainer Dyckerhoff. Further tests can be constructed based on mean hyperplane depth, the topic of Chapter 6.

The book includes plenty of useful graphs to help the reader see the zonoids and trimmed regions in two and three dimensions. Some additions that perhaps would have been helpful include some graphs comparing the different bivariate central regions in Section 3.5, some examples with data to compare the different notions of data depths in Section 4.3, and an internet location for the software for computing the data depths and multivariate central regions, in addition to the overview sections on algorithms (Sec. 3.9, 4.5). The computational details are nontrivial and are in papers published in COMPSTAT conference proceedings.

In addition to ideas useful in statistics, the book provides results on stochastic comparisons with applications in probability, operations research, and economics. The lift zonoid (partial) ordering, based on set inclusion of lift zonoids, and the lift zonoid volume ordering are stochastic orderings among probability distributions leading to multivariate indices of dispersion and measures of economic disparity and concentration when variables have an economic context. Multivariate versions of Gini indices are obtained. Also, with fixed univariate margins, dependence orders are proposed.

The book has elegant mathematical theory. To follow the mathematical details, the reader needs to be familiar with basic terminology and results of convex analysis and measure theory. Those interested mainly in applications can still benefit from reading Chapter 1 and some sections of subsequent chapters.

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**Principal Component Analysis (2nd ed.).**

I. T. JOLLiffe. New York: Springer-Verlag, 2002. ISBN: 0-387-95442-2. xxix + 486 pp. $89.95 (H).

This book is one of the very few texts entirely devoted to principal component analysis (PCA). The second edition is usefully expanded and updated from the first edition; thus it is very well worth considering this edition, even if one is familiar with the first. The book offers a thorough introduction to PCA. Very nice features are the carefully discussed links between PCA and related techniques, which enable the reader to position the technique, and the discussion of recently developed variants of PCA. Throughout, numerous references to relevant literature are provided. This book will be useful as an introduction to PCA as well as a reference. To fully appreciate the book, the reader should, at the very least, be familiar with the basics of matrix algebra and statistics. The book would be less suitable for use as a classroom textbook, mainly because it contains no exercises. Generally, the wide area of PCA is covered fairly well. However, the statement on the cover promising that the book “is once again the definitive text on the subject” is somewhat overstated. Little attention is paid to the perspective on PCA usually taken in the social sciences. Because social scientists are among the bulk consumers of PCA, it would be nice to find more on their viewpoint in a definitive text on PCA.

The book starts with a short introduction to principal components and a nice brief historical overview. The origins of a topic often offer insight into its current developments, and this discussion is no exception.

Chapter 2 thoroughly discusses the mathematical and statistical properties of population principal components. Chapter 3 presents its sample counterparts plus a couple of topics that are relevant in the context of samples only. It is highly instructive that the population and sample versions of PCA are treated separately, bringing the important distinction between the two to the reader’s attention. A section of Chapter 3 is devoted to inference in PCA. Unfortunately, hardly any attention is paid to inference in the remainder of the book. The author justifies this approach by remarking that “a description of the sample, rather than inference about the underlying population is often what is required” (p. 68). In my experience, however, researchers often wish to generalize their PCA results to the underlying population, but they simply do not know how to proceed. Then, the results of a PCA performed on sample data are often interpreted as if they were valid for the whole population, without assessing the degree of uncertainty in the parameter estimates. The widespread use of this practice should warrant further discussion of inference in PCA.

PCA can be based on the covariance or on the correlation matrix. The rationale and the consequences of each choice are treated thoroughly. This discussion is interesting both from theoretical and practical standpoints.

Principal components can be defined in a number of ways, which differ in the lengths of the vectors of coefficients used to compute the principal components and, as a result, in the lengths of the principal components themselves. In this book, the apparent strong preference is for setting the lengths of the coefficient
vectors equal to 1. However, because alternative scalings of the coefficients are so widely used, at least in the social sciences, more attention could be devoted to this topic in the technical introductory Chapters 2 and 3. A thorough discussion of the merits and demerits of the various approaches would also be valuable. At certain points in the book, attention is paid to the consequences of the various choices, but this is kept somewhat hidden. A more serious problem is the interchangeable use of the terms “coefficients” and “loadings.” The latter is correct for the scaling of the coefficients adopted in the book, but is incorrect for other scalings. The widespread use of alternative scaling approaches should justify a more thorough discussion than simply remarking that some authors distinguish between the two terms, and that the two terms are used interchangeably (p. 6). This would also make the book more accessible to readers accustomed to a different scaling approach, especially if they were unaware of the various alternatives before they started reading the book occasionally.

Chapter 4 offers a number of useful empirical examples that give the reader a good idea of the wide range of applications available, the aspects of the data to consider before performing PCA, and the interpretation of the solutions.

Chapter 5 deals with the graphical representation of data using principal components. Apart from plotting the principal components themselves, related graphical representation techniques, such as principal coordinate analysis, biplots and correspondence analysis, are discussed. It is particularly informative that the relationships between PCA and the related techniques are explained.

Chapter 6 treats the problem of selecting the number of components to retain. The many available procedures are carefully explained. However, the discussion of the relationships between the techniques and the recommendations for selecting a technique in practice is somewhat unsatisfactory, mainly because of the lack of background on the various approaches. I completely agree with the main message on pages 132–133 that “different objectives for a PCA lead to somewhat different requirements concerning how many PC’s to retain”, but it would be very helpful nonetheless to give the reader an idea of the different objectives and their associated requirements. Various approaches to the selection of a subset of variables are treated as well, and are nicely illustrated by empirical examples.

The relationship between factor analysis and principal component analysis is highlighted in Chapter 7. This material is highly useful, as so many misconceptions are common. The theoretical comparison is very instructive and clear. Unfortunately, the empirical example might be confusing. It is suggested in the introduction and the heading of the section (Sec. 7.4) that a factor analysis will be performed, but a closer reading of the text reveals that only a PCA is performed. It would have been instructive to have a comparison of the solutions of a PCA and a factor analysis. In the concluding remarks, it is said that rotation, being one of the main ideas of factor analysis, can be used in PCA as well. Here, the fact is overlooked that rotation is inseparably connected to PCA in a large application field of PCA, namely the social sciences.

The use of principal components to reduce the multicollinearity problem in regression is treated in Chapter 8. A nice overview is given of the various approaches, of which principal component regression and its variants are the main ones. Also, relationships with related techniques are discussed.

The use of PCA in discriminant analysis, cluster analysis, and canonical correlation analysis is highlighted in Chapter 9. This discussion has a nice side effect, namely the clarification of the three topics itself and their relationships.

Chapter 10 deals with various aspects of outliers and robust estimation. The role that PCA can play in the detection of outliers is discussed. Influential observations (i.e., observations heavily influencing the results of an analysis) are discussed. The finding that observations may be influential for the coefficients of a principal component but not for the explained variance of a principal component (and vice versa) is explained. Attention is also devoted to robust estimation of principal components, which implies that the effect of outliers on the analysis is downweighted.

The issue of rotation and interpretation of principal component is not treated until Chapter 11. The author has taken a clear position against the general use of rotation. However, because the term “rotation” is used occasionally before Chapter 11, an earlier treatment would be justified. Because rotation plays such a large role in certain application areas of PCA, a more extensive treatment of the topic would not be out of place. Besides, the arguments presented against the use of rotation are not quite convincing to me. For example, one of the arguments is that the variance of the components is redistributed among the components, and, as a result, information about the nature of any really dominant components may be lost. However, nothing prevents a researcher from having a look at both the rotated components and the principal components, and their associated variances. A second topic in Chapter 11 is a discussion of various techniques that can be used as an alternative to rotation. These techniques all aim at finding interpretable components by imposing constraints on the coefficients. In general, the components thus found are not principal components, because they do not explain the maximum amount of variance.

Chapter 12 deals with a very interesting topic. Such a nice overview of PCA for time series and other nonindependent data is rarely found. The first topics treated are PCA-related techniques used in atmospheric sciences, but the application field is probably broader, including, for example, the analysis of electroencephalogram data. Functional PCA—that is, PCA of data comprising curves—is explained next. The basics are explained in a nutshell very clearly, and again useful references for further reading are provided. Additionally, some attention is devoted to dependencies resulting from the use of a sampling scheme other than simple random sampling.

Chapter 13 discusses PCA for “special types of data”, covering a wide range of topics. An overview is presented of PCA approaches to discrete data, covering binary, ordinal, and nominal data. Correspondence analysis is discussed, in a clear way, as one of the PCA counterparts for nominal data. A section is devoted to PCA of compositional data, which are data comprising proportions that necessarily sum to unity. The problems associated with blind application of PCA to this type of data, and various adaptations to avoid those problems, are treated. Unfortunately, the empirical example of PCA on compositional data shows hardly a difference between the ordinary and the adapted PCA solutions, which makes the potential problems less recognizable. Justifiably, a rather large section is devoted to combined component analysis of data gathered from more than one population. A number of approaches are available to obtain common components for the populations. Flury’s common PCA consists of a hierarchy of models that differ in their degree of equality between populations. Unfortunately, the interpretation of the various models is left undiscussed. In estimating common principal components from sample data, it is necessary to assess whether the populations really do have the same common principal components. Methods based on a comparison of the various subspaces are discussed.

Kiers and Ten Berge’s simultaneous component analysis is presented as an alternative to common PCA. The next section covers PCA on incomplete datasets. Various approaches, including missing-data imputation and weighted PCA, pass by. It is somewhat infelicitous that no attention is paid to the sources of missingness and their consequences on the appropriateness of the various approaches.

A chapter on generalizations and adaptations of PCA closes the book. A wide range of nonlinear extensions of PCA are discussed, including the GIFI approach to PCA for nominal data, additive principal components, and nonlinear PCA using neural networks. A section is devoted to using weights, metrics, transformations, and centering in PCA. A number of approaches are described. However, the practical benefits, especially of using metrics, deserve more attention. The special technique of independent component analysis (ICA) is treated in the section on alternatives to PCA for nonnormal distributions. This might be somewhat confusing. ICA aims to find statistically independent components, which can be found only if those components are nonnormal. A completely different kind of generalization of PCA is for three-mode data, that is, data that can be usefully arranged in a three-dimensional array. Each of the axes of the array refers to one mode. An example is data pertaining to a number of individuals measured on the same variables in a number of conditions. The three-mode PCA presented in the book is a rather restrictive model for this kind of data, but a number of good references are provided for further reading.

An appendix gives the details of the computation of principal components. The section on PCA in statistical software has been dropped from the current edition for an understandable reason, namely that this information becomes outdated rapidly. However, users would probably be very interested in the implementations for PCA in the various packages and in software for the extensive range of models related to PCA discussed in this book, even if the information is not fully up to date.

All in all, Principal Component Analysis succeeds in giving a very good overview of the ins and outs of PCA and related techniques. This book aroused my interest for particular topics. The numerous useful references, including those to recent literature, give the reader ample opportunity to study those topics further.

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