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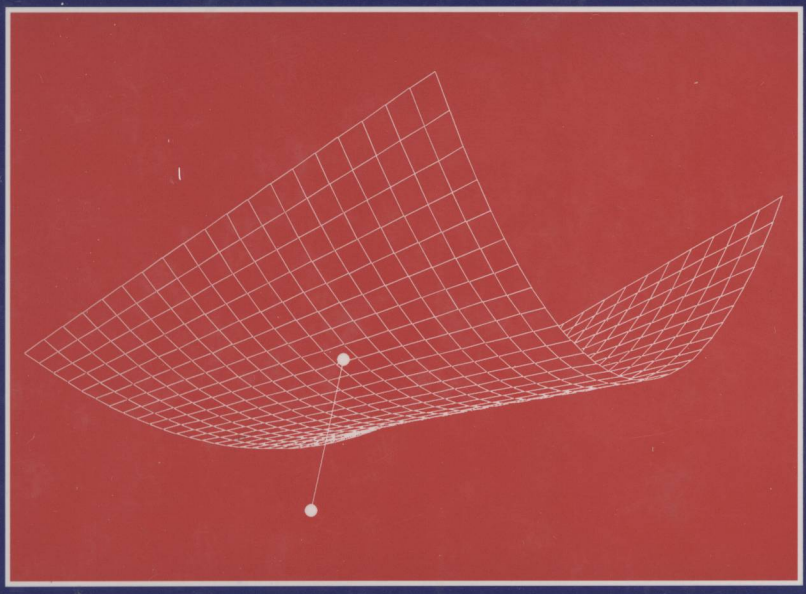
Mixed Models
Theory and Applications



Eugene Demidenko

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WILEY SERIES IN PROBABILITY AND STATISTICS

Mixed Models

Theory and Applications

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Mixed Models

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To my family

Preface

Technological advances change the world, and statistics is no exception. The cornerstone of classical statistics is the notion of *sample*. Today, data are richer: We may have repeated measurements with thousands of clusters; data may come in the form of shapes or images. This book is about statistical analysis of data that constitute a *sample of samples*. In the first ten chapters we discuss statistical models when data come in traditional form as a sequence of numbers. Chapter 11 deals with a sample (ensemble) of shapes and in Chapter 12 we discuss how to analyze an ensemble of images.

We take the statistical model-based approach to analyze data. Then the method of analysis is a derivative. Although the method sometimes comes first, the model-based approach has obvious advantages: assumptions are clearly formulated, and properties of several methods can be studied and compared. For example, least squares is a method of fitting, but its pros and cons can be fully understood only when a statistical model is put forward to describe how observations are obtained. Then least squares is deduced, for example, from maximum likelihood.

Statistical treatment is carried out under a unifying mixed effects approach. This approach becomes fruitful not only to analyze complex clustered data (a sample of samples) but also as a statistical model for penalization and a common ground for the Bayesian and frequentist camps.

Use of the mixed modeling technique in shape and image analysis is exciting and promising. Much work remains to reveal the full power of this statistical approach to these nontraditional statistical data.

The book is divided into three parts. The first eight chapters cover the theory of mixed models: the linear mixed effects (LME) model, the generalized linear mixed model (GLMM), and the nonlinear mixed effects (NLME) model. In Chapter 9 we discuss methods of model diagnostics and influential analysis. The last three chapters are devoted to applications: tumor regrowth, shape, and image. Major results and points of discussion in each chapter are written in lay language and are collected in *Summary points* sections so that the reader can get a quick chapter overview.

I look forward to hearing from readers and invite them to visit the book web site at

http://www.dartmouth.edu/~eugened

where some additional information with data and images is presented.

I would like to thank the many people I worked with on various projects that have led up to this book. First, I would like to mention my long-term collaboration with Therese Stukel and Tor Tosteson and thank them for their support. I am grateful to Harold Swartz and Jack Hoopes for the exposure to biological problems, and to the team led by Keith Paulsen, including Alex Hartov, Paul Meaney, and Brian Pogue, all from Dartmouth, who introduced me to the world of image reconstruction. Many thanks to John Baron, Margaret Karagas, and Mark Israel for creating a friendly scientific atmosphere. I am grateful to Ed Vonesh for discussion and his helpful comments.

Finally, thanks to the *Scientific Workplace,* a WYSIWYG version of the LaTeX typesetting system (http://www.mackichan.com)—it is hard to imagine writing this book without this software.

Eugene Demidenko

Hanover, New Hampshire
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