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Exploring Modeling with Data and Differential Equations Using R

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Welcome

This book is written for you: the student learning about modeling and differential equations. Perhaps you first encountered models, differential equations, and better yet, building plausible models from data in your Calculus course.

This book sits "at the intersection" of several different mathematics courses: differential equations, linear algebra, statistics, calculus, data science - as well as the partner disciplines of biology, chemsitry, physics, business, and economics. An important idea is one of *transference* where a differential equation model applied in once context can also be applied (perhaps with different variable names) in a separate context.

I intentionally emphasize models from biology and the environmental sciences, but throughout the text you can find examples from the other disciplines. I hope you see the connections of this content to your own intended major.

This book is divided into 4 parts:

1. Models with differential equations
2. Parameterizing models with data
3. Stability analysis for differential equations.
4. Stochastic differential equations

Unsure what about all these topics mean? Do not worry! The topics are presented with a "modeling first" paradigm that first introduces models, and equally important, how data are used to inform a model. The "conversation" between models and data are important to help build plausibility and confidence in a model. Stability analysis helps to solidify the connection between models and parameters (which may change the underlying dynamical stability). Finally the notion of *randomness* is extended with the introduction of stochastic differential equations.

0.0.0.1   Changes from the first edition

The first version of this text was in 2019, and based on feedback this version was significantly revised and updated. Here is a brief summary of changes:

- Every section was revised for clarity. Where appropriate, more specific instructions was given in each exercise, with an emphasis on gradually building understanding and difficulty.
- Additional solution techniques for solving differential equations are emphasized.
- New sections on systems of nonlinear equations and visualizing randomness
- Enhanced reliance on `ggplot2` and the `tidyverse` for data wrangling and visualization. Decreased reliance on "black box" functions to do it all.

These changes added just shy of 100 (!) pages of new content. Enjoy.

Computational code

This book makes heavy use of the R programming language, and unabashedly develops programming principles using the `tidyverse` syntax and programming approach. This is intentional to facilitate direct connections to courses in introductory data science or data visualization. Throughout my years learning (and teaching) different programming languages I have found R to be the most versatile and adaptable. The `tidyverse` syntax has also been transformational for me in my own work and as my students - the barrier to compute and write code is lowered.

There is a companion R package available called `demodelr` to run programs and functions in the text. Instructions to install this package are given in Section **??**. The minimum version of R Version 4.0.2 (2020-06-22) and RStudio is Version 1.4.1717.

The `demodelr` package uses the following `R` packages:

- `tidyverse` (and the associated packages) (Version 1.3.1)
- `GGally` (Version 2.1.2)
- `formula.tools` (Version 1.7.1)
- `expm` (Version 0.999-6)

There may be others that I am not aware of at the moment.

Questions? Comments? Issues?

Feel free to file an issue report: LINK

Acknowledgments

This book has been developed over the course of several years and has been written across two continents.

- **Augsburg University:** You have been my professional home for over 14 years and given me the space to be intellectually creative in my teaching. I have great colleagues to work with.

- **Augsburg University students:** Thank you for your interest in this topic, providing honest and insightful feedback about the course. This has been a work in progress (albeit bumpy at times).

- **My family:** Shannon, Colin, Grant, and Phoebe for humoring me while this project has been completed.

- **Waterparks, coffee shops, soccer practices:** Many times this was written "in the spaces" between work and home, and especially during downtimes when my kids could play. Turns out my kids love waterparks. Who knew?

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References