

Preface

Computational modeling plays an increasingly important role in biological and medical research, as well as in the medical device industry. Like other industries, successful development of medical devices and implants requires not only extensive testing (bench tests, animal experiments and human trials), but also extensive computational simulations which allow engineers to cost-effectively investigate system behavior and iterate the device design. These approaches are inherently multidisciplinary: biomedical engineers are required to understand not only the fundamental physical principles of their devices, but also how they interact with complex physiological systems at the cellular, tissue, and whole-organ levels. Computational models of such systems are typically multiphysics in nature. In the not too distant future, bioengineering modeling will also be used routinely in the clinic to tailor a range of individual therapies and treatment strategies based on patient-specific models.

It is evident that computational modeling is an important skill for biomedical engineers, and should form an indispensable component of modern curricula in biomedical engineering. This book grew from my own course, ‘Modelling Organs, Tissues and Devices’, taught to late-stage undergraduate and postgraduate engineering students at the Graduate School of Biomedical Engineering, UNSW. It covered a broad range of modeling topics, from electrical stimulation of tissues through to diffusion, biomechanics, heat transfer and fluid dynamics. Numerical software used for teaching the course were MATLAB and COMSOL Multiphysics—the former due to its prevalent use in engineering and the latter due to its multiphysics capabilities and appealing user interface. For their major project, students were required to submit a COMSOL model in any bioengineering field of their choice. Despite the popularity of the course, it became apparent there was no single book which could be used as recommended text which covered the range of topics taught, including numerical/analytical methods for solving ODE/PDEs, an overview of the various multiphysics principles involved, as well as how such models can be practically implemented in MATLAB and COMSOL. Hence, the idea for this book was born!

The text is divided into two parts: Part A covers basic modeling concepts as well as analytical and numerical methods for solving ODE/PDE systems. Part B covers specific physics applications in bioengineering. Each chapter also includes a set of problems, over 50 in total, with detailed answers provided in the solutions section, along with several worked-examples with code listings throughout the main text itself. Appendices A and B provide an introduction to MATLAB and COMSOL, respectively.

All models in the text were solved on a base-model MacBook Air 2013 laptop with 8G RAM. Some of the models took tens of minutes to solve, whilst others took only a few seconds. The MATLAB version employed was R2014b, and the COMSOL version was 5.2 (the latest at the time of writing). Most of these models could be solved using the standard base packages of MATLAB and COMSOL, whilst other models required optional add-ons such as MATLAB's Symbolic Math Toolbox or COMSOL's Nonlinear Structural Materials Module. Such instances whenever they occur are mentioned in the text.

Finally, I wish to acknowledge my family for their unwavering support throughout the four long years it took to complete this text, as well the encouragement and support from my colleagues at UNSW. A special mention to Jan-Philip Schmidt, my editor at Springer Verlag, for his patience and encouragement, as well as my many students and postdocs, past and present, whose MATLAB and/or COMSOL modeling works have inspired many examples throughout this text. They include Amr Al Abed, Siwei Bai, Tianruo Guo, Miganoosh Abramian, Khalid Alonazi, Siniša Sovilj, Yousef Alharbi, Azam Bakir, Chin Neng Leong, Bee Ting Chan, Abdulrahman Alqahtani, Mitra Mohd Addi, Shuhaida Yahud, Shijie Yin, Ben Hui, David Chan and Einly Lim. I have thoroughly treasured and learnt much from our interactions.

Sydney, Australia
May 2016

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Modelling Organs, Tissues, Cells and Devices
Using MATLAB and COMSOL Multiphysics

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2017, XIII, 502 p. 207 illus., Hardcover

ISBN: 978-3-642-54800-0