

Mathematical Biology

Second Edition
Steven Strogatz

Modeling Dynamic Biological Systems



Modeling Dynamic Biological Systems

Michael Small



Modeling Dynamic Biological Systems:

Modeling Dynamic Biological Systems. B. Hannon, M. Ruth, 1997-01 **Dynamic Systems Biology Modeling and Simulation** Joseph DiStefano III, 2015-01-10 Dynamic Systems Biology Modeling and Simulation consolidates and unifies classical and contemporary multiscale methodologies for mathematical modeling and computer simulation of dynamic biological systems from molecular cellular organ system on up to population levels The book pedagogy is developed as a well annotated systematic tutorial with clearly spelled out and unified nomenclature derived from the author's own modeling efforts publications and teaching over half a century Ambiguities in some concepts and tools are clarified and others are rendered more accessible and practical The latter include novel qualitative theory and methodologies for recognizing dynamical signatures in data using structural multicompartmental and network models and graph theory and analyzing structural and measurement data models for quantification feasibility The level is basic to intermediate with much emphasis on biomodeling from real biodata for use in real applications Introductory coverage of core mathematical concepts such as linear and nonlinear differential and difference equations Laplace transforms linear algebra probability statistics and stochastics topics The pertinent biology biochemistry biophysics or pharmacology for modeling are provided to support understanding the amalgam of math modeling with life sciences Strong emphasis on quantifying as well as building and analyzing biomodels includes methodology and computational tools for parameter identifiability and sensitivity analysis parameter estimation from real data model distinguishability and simplification and practical bioexperiment design and optimization Companion website provides solutions and program code for examples and exercises using Matlab Simulink VisSim SimBiology SAAMII AMIGO Copasi and SBML coded models A full set of PowerPoint slides are available from the author for teaching from his textbook He uses them to teach a 10 week quarter upper division course at UCLA which meets twice a week so there are 20 lectures They can easily be augmented or stretched for a 15 week semester course Importantly the slides are editable so they can be readily adapted to a lecturer's personal style and course content needs The lectures are based on excerpts from 12 of the first 13 chapters of DSBMS They are designed to highlight the key course material as a study guide and structure for students following the full text content The complete PowerPoint slide package 25 MB can be obtained by instructors or prospective instructors by emailing the author directly at joed@cs.ucla.edu *Mathematical Modeling of Dynamic Biological Systems* Ludwik Finkelstein, Ewart R. Carson, 1979 *Modeling Dynamic Biological Systems* Bruce Hannon, Matthias Ruth, 2014-07-05 Many biologists and ecologists have developed models that find widespread use in theoretical investigations and in applications to organism behavior disease control population and metapopulation theory ecosystem dynamics and environmental management This book captures and extends the process of model development by concentrating on the dynamic aspects of these processes and by providing the tools such that virtually anyone with basic knowledge in the Life Sciences can develop meaningful dynamic models Examples of the systems modeled in the book range

from models of cell development the beating heart the growth and spread of insects spatial competition and extinction to the spread and control of epidemics including the conditions for the development of chaos Key features easy to learn and easy to use software examples from many subdisciplines of biology covering models of cells organisms populations and metapopulations no prior computer or programming experience required Key benefits learn how to develop modeling skills and system thinking on your own rather than use models developed by others be able to easily run models under alternative assumptions and investigate the implications of these assumptions for the dynamics of the biological system being modeled develop skills to assess the dynamics of biological systems Computationally Modeling Dynamic Biological Systems

Katherine F. Jarvis,2021 **Dynamics of Biological Systems** Michael Small,2011-08-25 From the spontaneous rapid firing of cortical neurons to the spatial diffusion of disease epidemics biological systems exhibit rich dynamic behaviour over a vast range of time and space scales Unifying many of these diverse phenomena Dynamics of Biological Systems provides the computational and mathematical platform from which to understand the underlying processes of the phenomena Through an extensive tour of various biological systems the text introduces computational methods for simulating spatial diffusion processes in excitable media such as the human heart as well as mathematical tools for dealing with systems of nonlinear ordinary and partial differential equations such as neuronal activation and disease diffusion The mathematical models and computer simulations offer insight into the dynamics of temporal and spatial biological systems including cardiac pacemakers artificial electrical defibrillation pandemics pattern formation flocking behaviour the interaction of autonomous agents and hierarchical and structured network topologies Tools from complex systems and complex networks are also presented for dealing with real phenomenological systems With exercises and projects in each chapter this classroom tested text shows students how to apply a variety of mathematical and computational techniques to model and analyze the temporal and spatial phenomena of biological systems MATLAB implementations of algorithms and case studies are available on the author s website Dynamic Models and Control of Biological Systems Vadrevu Sree Hari Rao,Ponnada Raja Sekhara

Rao,2009-07-30 Mathematical Biology has grown at an astonishing rate and has established itself as a distinct discipline Mathematical modeling is now being applied in every major discipline in the biological sciences Though the field has become increasingly large and specialized this book remains important as a text that introduces some of the exciting problems which arise in the biological sciences and gives some indication of the wide spectrum of questions that modeling can address

Modeling Nonlinear Behavior of Dynamic Biological Systems Maryam Masnadi-Shirazi,2018 With the availability of large scale data acquired through high throughput technologies computational systems biology has made substantial progress towards partially modeling biological systems In this dissertation we intend to focus on deciphering the dynamics of such systems through data driven analysis of multivariate time course data We develop integrative frameworks to study the following problems 1 time varying causal inference when the number of samples exceeds the number of variables

overdetermined case 2 dynamic causal network reconstruction when the number of variables exceeds the data samples
 underdetermined case 3 forecasting the dynamic behavior of complex chaotic systems from short and noisy time series data
 In the first scenario we utilize the notion of Granger causality identified by a first order vector autoregressive VAR model on phosphoproteomic measurements to unravel the crosstalk between various phosphoproteins in three distinct time intervals In scenario 2 we use a non parametric change point detection CPD algorithm on transcriptional time series data from a mouse cell cycle to estimate temporal patterns that can be associated with different phases of the cell cycle In the second scenario the problem becomes more complex as the number of variables exceeds the number of time series data and we use a higher order VAR models to estimate causal interactions among cell cycle genes To solve this ill posed problem we use Least Absolute Shrinkage and Selection Operator LASSO and select the regularization parameters through Estimation Stability with Cross Validation ES CV leading to more biologically meaningful results LASSO ES CV is applied to temporal intervals associated with the G1 S and G2 M phases of the cell cycle to estimate phase specific intracellular interactions In problem 3 we develop a nonparametric forecasting algorithm for chaotic dynamic systems Multiview Radial Basis Function Network MV RBFN that outperforms a model free approach Multiview Embedding MVE In this algorithm the forecast skill of all possible manifolds views reconstructed from a combination of variables and their time lags is assessed and ranked from best to worst MV RBFN uses the top k views as the inputs of a neural network to approximate a nonlinear function f that maps the past events of a dynamic system as the input to future values as the output

Modeling Biological Systems: James W. Haefner, 2005-12-05 I Principles 1 1 Models of Systems 3 1 1 Systems Models and Modeling 3 1 2 Uses of Scientific Models 4 1 3 Example Island Biogeography 6 1 4 Classifications of Models 10 1 5 Constraints on Model Structure 12 1 6 Some Terminology 12 1 7 Misuses of Models The Dark Side 13 1 8 Exercises 15 2 The Modeling Process 17 2 1 Models Are Problems 17 2 2 Two Alternative Approaches 18 2 3 An Example Population Doubling Time 24 2 4 Model Objectives 28 2 5 Exercises 30 3 Qualitative Model Formulation 32 3 1 How to Eat an Elephant 32 3 2 Forrester Diagrams 33 3 3 Examples 36 3 4 Errors in Forrester Diagrams 44 3 5 Advantages and Disadvantages of Forrester Diagrams 44 3 6 Principles of Qualitative Formulation 45 3 7 Model Simplification 47 3 8 Other Modeling Problems 49 viii Contents 3 9 Exercises 53 4 Quantitative Model Formulation I 4 1 From Qualitative to Quantitative Finite Difference Equations and Differential Equations 4 2 4 3 Biological Feedback in Quantitative Models 4 4 Example Model 4 5 Exercises 5 Quantitative Model Formulation II 81 5 1 Physical Processes 81 5 2 Using the Toolbox of Biological Processes 89 5 3 Useful Functions 96 5 4 Examples 102 5 5 Exercises 104 6 Numerical Techniques 107 6 1 Mistakes Computers Make 107 6 2 Numerical Integration 110 6 3 Numerical Instability and Stiff Equations 115

Models of Life Kim Sneppen, 2014-10-02 An overview of current models of biological systems reflecting the major advances that have been made over the past decade

Mathematical Modeling of Biological Systems Harvey J. Gold, 1977 The modeling process an overview Dimension and similarity Probability models Dynamic

processes Interacting dynamic processes Feedback control and stability of biological systems Curve fitting estimating the parameters Computing *Modeling Dynamic Phenomena in Molecular and Cellular Biology* Lee A. Segel, 1984-03-30 The dynamic development of various processes is a central problem of biology and indeed of all the sciences The mathematics describing that development is in general complicated because the models that are realistic are usually nonlinear Consequently many biologists may not notice a possible application of theory They may be unable to decide whether a particular model captures the essence of a system or to appreciate that analysis of a model can reveal important aspects of biological problems and may even describe in detail how a system works The aim of this textbook is to remedy the situation by adopting a general approach to model analysis and applying it several times to problems drawn primarily from molecular and cellular biology of gradually increasing biological and mathematical complexity Although material of considerable sophistication is included little mathematical background is required only some exposure to elementary calculus appendixes supply the necessary mathematics and the author concentrates on concepts rather than techniques He also emphasizes the role of computers in giving a full picture of model behavior and complementing more qualitative analysis Some problems suitable for computer analysis are also included This is a class tested textbook suitable for a one semester course for advanced undergraduate and beginning graduate students in biology or applied mathematics It can also be used as a source book for teachers and a reference for specialists **Dynamic Biosystem Modeling & Simulation Methodology -**

Integrated & Accessible Joseph DiStefano, 3rd, 2019-09-16 This textbook is uniquely crafted for use in teaching undergraduate students in the life math computer and other sciences and engineering It is INTRODUCTORY LEVEL for students who have taken or are currently completing their undergraduate math requirements and are acquiring analytical thinking and doing skills along with introductory biology chemistry and physics subject matter It's about learning HOW to model and simulate dynamic biological systems which also makes it useful for graduate students and professional researchers who want a more rigorous treatment of introductory life science math modeling integrated with the biology It brings together the multidisciplinary pedagogy of these subjects into a SINGLE INTRODUCTORY MODELING METHODOLOGY COURSE crystalizing the experience of an author who has been teaching dynamic biosystems modeling and simulation methodology for the life sciences for more than 50 years DiStefano maximizes accessibility and systems math biology integration without diminishing conceptual rigor Minimally essential applied math and SYSTEMS ENGINEERING METHODS are included along with a synopsis of the biology and physiology underlying dynamic biosystem modeling all in a modeling pedagogy context This textbook fills a major need in the training of contemporary biology students Dynamic biosystems modeling methodology is presented over 12 distinctive chapters primarily with systems diagrams and simple differential equations and algebra for expressing them quantitatively integrated with the biology Solving and analyzing quantifying the biomodels are then accomplished by simulation using a facile control system simulation language Simulink a

GUI Matlab toolbox that emulates control systems diagramming rather than by coding the model in a standard computer programming language. Students see and work with the system model not the code. A big plus: Higher math and complex analytical solutions are avoided. Each chapter begins with a list of LEARNING GOALS to help with both perspective for the chapter material and retrospective to measure learning. EXERCISES for the student at the end of each chapter are designed to test and reinforce learning. A SOLUTIONS MANUAL for chapter exercises is available to qualified instructors from the author as are LECTURE SLIDES and LAB ASSIGNMENTS AND SOLUTIONS for courses that adopt the textbook for student use.

Systems Biology Jinzhi Lei, 2021-05-13 This book discusses the mathematical simulation of biological systems with a focus on the modeling of gene expression, gene regulatory networks and stem cell regeneration. The diffusion of morphogens is addressed by introducing various reaction diffusion equations based on different hypotheses concerning the process of morphogen gradient formation. The robustness of steady state gradients is also covered through boundary value problems. The introduction gives an overview of the relevant biological concepts: cells, DNA, organism development and provides the requisite mathematical preliminaries on continuous dynamics and stochastic modeling. A basic understanding of calculus is assumed. The techniques described in this book encompass a wide range of mechanisms from molecular behavior to population dynamics and the inclusion of recent developments in the literature together with first hand results make it an ideal reference for both new students and experienced researchers in the field of systems biology and applied mathematics.

Dynamics of Complex Interconnected Biological Systems Jennings, Mees, Vincent, 2012-12-06 This volume contains the proceedings of the U S Australia workshop on Complex Interconnected Biological Systems held in Albany Western Australia January 1-5 1989. The workshop was jointly sponsored by the Department of Industry Trade and Commerce Australia and the National Science Foundation USA under the US Australia agreement. Biological systems are typically hard to study mathematically. This is particularly so in the case of systems with strong interconnections such as ecosystems or networks of neurons. In the past few years there have been substantial improvements in the mathematical tools available for studying complexity. Theoretical advances include substantially improved understanding of the features of nonlinear systems that lead to important behaviour patterns such as chaos. Practical advances include improved modelling techniques and deeper understanding of complexity indicators such as fractal dimension. Game theory is now playing an increasingly important role in understanding and describing evolutionary processes in interconnected systems. The strategies of individuals which affect each other's fitness may be incorporated into models as parameters. Strategies which have the property of evolutionary stability result from particular parameter values which may be the main feature of living determined using game theoretic methods. Since systems evolve it seems appropriate that any model used to describe such systems should have this feature as well. Evolutionary game theory should lead the way in the development of such methods.

Mathematical Modelling of Dynamic Biological Systems Ludwick Finkelstein, Ewart R. Carson, 1979-01-01

Model, Simulate, and

Analyze Biological Systems with MATLAB J. Perkins, 2018-01-04 SimBiology provides an app and programmatic tools to model simulate and analyze dynamic systems focusing on pharmacokinetic pharmacodynamic PK PD and systems biology applications It provides a block diagram editor for building models or you can create models programmatically using the MATLAB language SimBiology includes a library of common PK models which you can customize and integrate with mechanistic systems biology models A variety of model exploration techniques let you identify optimal dosing schedules and putative drug targets in cellular pathways SimBiology uses ordinary differential equations ODEs and stochastic solvers to simulate the time course profile of drug exposure drug efficacy and enzyme and metabolite levels You can investigate system dynamics and guide experimentation using parameter sweeps and sensitivity analysis You can also use single subject or population data to estimate model parameters The fundamental content of this book is the following App for PK PD and mechanistic systems biology modeling Ordinary differential equations ODEs and stochastic solvers Library of PK models Parameter estimation techniques for single subject and population data including nonlinear mixed effects models Sensitivity analysis and parameter sweeps for investigating parameter effects on system dynamics Diagnostic plots for individual and population fits Methods for creating and optimizing dosing schedules Mathematical Modeling of Complex Biological Systems Abdelghani Bellouquid, Marcello Delitala, 2008-11-01 This book describes the evolution of several socio biological systems using mathematical kinetic theory Specifically it deals with modeling and simulations of biological systems whose dynamics follow the rules of mechanics as well as rules governed by their own ability to organize movement and biological functions It proposes a new biological model focused on the analysis of competition between cells of an aggressive host and cells of a corresponding immune system Proposed models are related to the generalized Boltzmann equation The book may be used for advanced graduate courses and seminars in biological systems modeling **Modeling Biological Systems** James W Haefner, 1996-07-01 **Modeling Dynamic Nonlinear Systems** Keith Richard Criddle, 1989

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