

This book gives a presentation of stochastic epidemic models and their statistical analysis. It focuses on simple epidemic models making use of modern probabilistic and statistical methods such as coupling, diffusion approximation, random graphs, likelihood theory for counting processes, martingales, the EM-algorithm, and MCMC methods. These methods are presented in a general form keeping the technical level at a minimum and then applied to epidemic models. The reader will learn about the theory of epidemic models and be introduced to many useful general techniques from probability and statistics. The lecture notes require an undergraduate-level knowledge of probability and statistics and is well suited for a one-semester graduate course.

Håkan Andersson works as a risk analyst in a Swedish bank. Previously, he was a researcher in the Department of Mathematics at Stockholm University, Sweden; models of epidemic spread were his main research field. He has published several papers on epidemic modelling in applied probability journals.

Tom Britton is associate professor at the Department of Mathematics at Uppsala University, Sweden. He is the author of a dozen papers in epidemic modelling and its statistical analysis. He is also director of undergraduate studies at the Department of Mathematics at Uppsala University and secretary of the Swedish Statistical Association.

Springer-Verlag

175 Fifth Avenue, New York, New York 10010, USA

Heidelberger Platz 3, 1000 Berlin 33, Germany

Tiergartenstrasse 17, D-69121 Heidelberg, Germany

13-3, Hongo 3-chome, Bunkyo-ku, Tokyo 113, Japan

Provença, 388, 1a planta, E-08025 Barcelona, Spain

Room 701 Mirror Tower, 61, Mody Road, Tsimshatsui, Kowloon, Hong Kong

8 Alexandra Road, Wimbledon, London SW19 7JZ, England

Via Podgora 4, I-20122 Milano, Italy

26, rue de Cernes, F-75005 Paris, France

04-01 Cencon I, 1 Tannery Road, Singapore 1334

ISBN 978-0-387-95050-1



9 780387 950501



Part I: STOCHASTIC MODELLING	1
Chapter 1. Introduction	3
1.1. Stochastic versus deterministic models	3
1.2. A simple epidemic model: The Reed-Frost model	4
1.3. Stochastic epidemics in large communities	6
1.4. History of epidemic modelling	7
Exercises	9
Chapter 2. The standard SIR epidemic model	11
2.1. Definition of the model	11
2.2. The Sellke construction	12
2.3. The Markovian case	14
2.4. Exact results	15
Exercises	18
Chapter 3. Coupling methods	19
3.1. First examples	19
3.2. Definition of coupling	22
3.3. Applications to epidemics	22
Exercises	26
Chapter 4. The threshold limit theorem	27
4.1. The imbedded process	27
4.2. Preliminary convergence results	28

4.3. The case $m_n/n \rightarrow \mu > 0$ as $n \rightarrow \infty$	30
4.4. The case $m_n = m$ for all n	32
4.5. Duration of the Markovian SIR epidemic	34
Exercises	36
Chapter 5. Density dependent jump Markov processes	39
5.1. An example: A simple birth and death process	39
5.2. The general model	40
5.3. The Law of Large Numbers	41
5.4. The Central Limit Theorem	43
5.5. Applications to epidemic models	46
Exercises	48
Chapter 6. Multitype epidemics	51
6.1. The standard SIR multitype epidemic model	51
6.2. Large population limits	53
6.3. Household model	55
6.4. Comparing equal and varying susceptibility	56
Exercises	61
Chapter 7. Epidemics and graphs	63
7.1. Random graph interpretation	64
7.2. Constant infectious period	65
7.3. Epidemics and social networks	66
7.4. The two-dimensional lattice	70
Exercises	72
Chapter 8. Models for endemic diseases	73
8.1. The SIR model with demography	73
8.2. The SIS model	77
Exercises	83

Part II: ESTIMATION	85
Chapter 9. Complete observation of the epidemic process	87
9.1. Martingales and log-likelihoods of counting processes	87
9.2. ML-estimation for the standard SIR epidemic	91
Exercises	94
Chapter 10. Estimation in partially observed epidemics	99
10.1. Estimation based on martingale methods	99
10.2. Estimation based on the EM-algorithm	103
Exercises	105
Chapter 11. Markov Chain Monte Carlo methods	107
11.1. Description of the techniques	107
11.2. Important examples	109
11.3. Practical implementation issues	111
11.4. Bayesian inference for epidemics	113
Exercises	114
Chapter 12. Vaccination	117
12.1. Estimating vaccination policies based on one epidemic	117
12.2. Estimating vaccination policies for endemic diseases	120
12.3. Estimation of vaccine efficacy	123
Exercises	124
References	127
Subject index	135