

## SOLUTION (CHAPTER 1) OF INTRODUCTION TO STOCHASTIC PROCESSES -HOEL PORT STONE

1(a)

Using the definition of conditional probability, we have that

$$P(X_2 = 0 | X_0 = 0, X_1 = 0) = \frac{P(X_2 = 0, X_0 = 0, X_1 = 0)}{P(X_0 = 0, X_1 = 0)} = \frac{P(X_2 = 0, X_0 = 0, X_1 = 0)}{P(X_0 = 0, X_1 = 0)}$$

Now, the probability in the numerator can be written as

$$P(X_2 = 0, X_1 = 0, X_0 = 0) = P(X_2 = 0, X_1 = 0 | X_0 = 0)P(X_0 = 0) = (1 - p)^2 \nu_0(0)$$

where we have used Markov property of the process. Similarly, use the law of the total probability that the numerator is equal to

$$P(X_2 = 0, X_1 = 0) = P(X_2 = 0, X_1 = 0, X_0 = 0) + P(X_2 = 0, X_1 = 0, X_0 = 1)$$

Similarly as in the numerator, we obtain that

$$P(X_2 = 0, X_1 = 0) = (1 - p)^2 \nu_0(0) + q \nu_0(1)$$

Therefore, the required probability is equal to

$$(b) \quad P(X_2 = 0 | X_0 = 0, X_1 = 0) = \frac{(1 - p)^2 \nu_0(0)}{(1 - p)^2 \nu_0(0) + q \nu_0(1)} = \frac{(1 - p)^2}{(1 - p)^2 + qp}$$

Observe that  $\{X_1 \neq X_2\}$  if and only if  $\{X_1 = 0, X_2 = 1\}$  or  $\{X_1 = 1, X_2 = 0\}$ . Therefore, we have

$$P(X_1 \neq X_2) = P(X_1 = 0, X_2 = 1) + P(X_1 = 1, X_2 = 0)$$

Now, let's calculate these two summands. The idea is simple - we intercept with the initial state  $X_0$ . Hence

$$P(X_1 = 0, X_2 = 1) = P(X_0 = 0, X_1 = 0, X_2 = 1) + P(X_0 = 1, X_1 = 0, X_2 = 1)$$

and similarly as in part (a), we get that

$$P(X_1 = 0, X_2 = 1) = \nu_0(0)(1 - p)q + \nu_0(1)qp$$

Use the same idea to obtain that

$$P(X_1 = 1, X_2 = 0) = \nu_0(0)qp + \nu_0(1)(1 - q)p$$

so we get

$$P(X_1 \neq X_2) = \nu_0(0)(1 - p)q + \nu_0(1)qp + \nu_0(0)qp + \nu_0(1)(1 - q)p = \nu_0(0)(1 - p - q)(p - q) + q(p + 1 - q)p$$

where we use that  $\nu_0(0) + \nu_0(1) = 1$ .

2.

Observe that the state space of this Markov chain is  $\mathcal{S} = \{0, 1, \dots, d\}$ . Take any  $k \in \mathcal{S}$  and suppose that  $X_n = k$ . Let's find the conditional distribution of  $X_{n+1}$  given  $X_n = k$ .

If  $X_n = k$ , there is  $k$  black balls in the first box. Therefore, after one additional draw, the number of black balls can drop for one (if  $k \neq 0$ ), it can remain the same or it can rise for one (if  $k \neq d$ ).

The number of black balls drop for one if we draw a black ball from the first box and a white ball from the second box. Since we have  $k$  black balls in the first box and  $d - k$  white balls in the second box, the required probability is equal to

$$P(X_{n+1} = k - 1 | X_n = k) = \left(\frac{k}{d}\right)^2$$

The number of black balls remains the same if we draw balls of the same color from both boxes. Therefore, the required probability is equal to

$$P(X_{n+1} = k | X_n = k) = \frac{k}{d} \cdot \frac{d - k}{d} + \frac{d - k}{d} \cdot \frac{k}{d} = \frac{2k(d - k)}{d^2}$$

Finally, the number of black balls rises for one if we draw a white ball from the first box and a black ball from the second box. Therefore, the required probability is equal to

$$P(X_{n+1} = k + 1 | X_n = k) = \left(\frac{d - k}{d}\right)^2$$

Therefore, the transition function is equal to

$$P(k, l) = \begin{cases} (k/d)^2 & , l = k - 1 \\ 2k(d - k)/d^2 & , l = k \\ ((d - k)/d)^2 & , l = k + 1 \\ 0 & , \text{otherwise} \end{cases}$$

3.

The state space remains the same,  $\mathcal{S} = \{0, 1, 2, \dots\}$ . If there is no customers in the queue, the probability that there is  $y$  of them in the queue after one step is simply  $f(x)$ . Therefore

$$P(0, y) = f(x)$$

Now, suppose that there is  $x$  people in the queue and we want to find the probability that there is  $y$  people in the queue after one step. One person is served with probability  $p$ , so we have  $x - 1$  people in the queue left. Therefore, we have to add  $y - x + 1$  people in the queue and probability for that is  $f(y - x + 1)$ . On the other hand, one person is not served with probability  $1 - p$ , so we have  $x$  people in the queue left. Therefore, we have to add  $y - x$  people in the queue and probability for that is  $f(y - x + 1)$ . Hence,

$$P(x, y) = pf(y - x + 1) + (1 - p)f(y - x)$$

# Hoel Port Stone Solutions

**J Elliott**



## Hoel Port Stone Solutions:

**Introduction to Stochastic Processes** Paul G. Hoel, Sidney C. Port, Charles J. Stone, 1986-12-01 An excellent introduction for computer scientists and electrical and electronics engineers who would like to have a good basic understanding of stochastic processes This clearly written book responds to the increasing interest in the study of systems that vary in time in a random manner It presents an introductory account of some of the important topics in the theory of the mathematical models of such systems The selected topics are conceptually interesting and have fruitful application in various branches of science and technology

**Applications of Nonlinear Dynamics To Developmental Process Modeling** Karl M. Newell, Peter C.M. Molenaar, 2014-03-05 There has been an increasing interest in the application of dynamical systems to the study of development over the last decade The explosion of the dynamical systems framework in the physical and biological sciences has opened the door to a new Zeitgeist for studying development This appeal to dynamical systems by developmentalists is natural given the intuitive links between the established fundamental problems of development and the conceptual and operational scope of nonlinear dynamical systems This promise of a new approach and framework within which to study development has led to some progress in recent years but also a growing appreciation of the difficulty of both fully examining the new metaphor and realizing its potential Divided into 4 parts this book is a result of a recent conference on dynamical systems and development held at Pennsylvania State University The first 3 parts focus on the content domains of development that have given most theoretical and empirical attention to the potential applications of dynamical systems physical growth and movement cognition and communication These parts show that a range of nonlinear models have been applied to a host of developmental phenomena Part 4 highlights two particular methodological issues that hold important implications for the modeling of developmental phenomena with dynamical systems techniques

**Journal of the American Statistical Association** American Statistical Association, 1981 A scientific and educational journal not only for professional statisticians but also for economists business executives research directors government officials university professors and others who are seriously interested in the application of statistical methods to practical problems in the development of more useful methods and in the improvement of basic statistical data

*Discovering Evolution Equations with Applications* Mark McKibben, 2011-06-03 Most existing books on evolution equations tend either to cover a particular class of equations in too much depth for beginners or focus on a very specific research direction Thus the field can be daunting for newcomers to the field who need access to preliminary material and behind the scenes detail Taking an applications oriented conversation

[Applications of Operations Research and Management Science](#) G. S. R. Murthy, 2015-06-15 This book includes case studies that examine the application of operations research to improve or increase efficiency in industry and operational activities This collection of living case studies is all based on the author's 30 year career of consulting and advisory work These true to life industrial applications illustrate the research and development

of solutions as well as potential implementation and integration problems that may occur when adopting these methods into a business. Among the topics covered in the chapters include optimization in circuit board manufacturing, Decision Support System (DSS) for plant loading and dispatch planning as well as development of important test procedures for tyre and pharma industry with shelf life constraints. In particular, the study on deckle optimization should be of great help to managers in paper industry and consultants for development of deckle optimization software. The application of operations research throughout the industry makes it an ideal guide for industrial executives, professionals and practitioners responsible for quality and productivity improvement.

**Intuitive Probability and Random Processes using MATLAB®** Steven Kay, 2006-03-20. Intuitive Probability and Random Processes using MATLAB is an introduction to probability and random processes that merges theory with practice. Based on the author's belief that only hands-on experience with the material can promote intuitive understanding, the approach is to motivate the need for theory using MATLAB examples followed by theory and analysis and finally descriptions of real world examples to acquaint the reader with a wide variety of applications. The latter is intended to answer the usual question: Why do we have to study this? Other salient features are heavy reliance on computer simulation for illustration and student exercises, the incorporation of MATLAB programs and code segments, discussion of discrete random variables followed by continuous random variables to minimize confusion, summary sections at the beginning of each chapter, in-line equation explanations, warnings on common errors and pitfalls, over 750 problems designed to help the reader assimilate and extend the concepts. Intuitive Probability and Random Processes using MATLAB is intended for undergraduate and first year graduate students in engineering. The practicing engineer as well as others having the appropriate mathematical background will also benefit from this book. About the Author: Steven M. Kay is a Professor of Electrical Engineering at the University of Rhode Island and a leading expert in signal processing. He has received the Education Award for outstanding contributions in education and in writing scholarly books and texts from the IEEE Signal Processing Society and has been listed as among the 250 most cited researchers in the world in engineering.

**Introduction to Stochastic Processes Using R** Sivaprasad Madhira, Shailaja Deshmukh, 2023-11-03. This textbook presents some basic stochastic processes, mainly Markov processes. It begins with a brief introduction to the framework of stochastic processes followed by a thorough discussion on Markov chains, which is the simplest and the most important class of stochastic processes. The book then elaborates the theory of Markov chains in detail, including classification of states, the first passage distribution, the concept of periodicity and the limiting behaviour of a Markov chain in terms of associated stationary and long-run distributions. The book first illustrates the theory for some typical Markov chains such as random walk, gambler's ruin problem, Ehrenfest model, and Bienayme Galton-Watson branching process and then extends the discussion when the time parameter is continuous. It presents some important examples of a continuous-time Markov chain which include Poisson process, birth process, death process, birth and death processes and their variations. These processes play a

fundamental role in the theory and applications in queuing and inventory models population growth epidemiology and engineering systems The book studies in detail the Poisson process which is the most frequently applied stochastic process in a variety of fields with its extension to a renewal process The book also presents important basic concepts on Brownian motion process a stochastic process of historic importance It covers its few extensions and variations such as Brownian bridge geometric Brownian motion process which have applications in finance stock markets inventory etc The book is designed primarily to serve as a textbook for a one semester introductory course in stochastic processes in a post graduate program such as Statistics Mathematics Data Science and Finance It can also be used for relevant courses in other disciplines Additionally it provides sufficient background material for studying inference in stochastic processes The book thus fulfils the need of a concise but clear and student friendly introduction to various types of stochastic processes

**Pattern Theory** David Mumford, Agnès Desolneux, 2010-08-09 Pattern theory is a distinctive approach to the analysis of all forms of real world signals At its core is the design of a large variety of probabilistic models whose samples reproduce the look and feel of the real signals their patterns and their variability Bayesian statistical inference then allows you to apply these models in the analysis of new signals This book treats the mathematical tools the models themselves and the computational algorithms for applying statistics to analyze six representative classes of signals of increasing complexity The book covers patterns in text sound and images Discussions of images include recognizing characters textures nature scenes and human faces The text includes online access to the materials data code etc needed for the exercises

**Classical and Spatial Stochastic Processes** Rinaldo B. Schinazi, 2012-12-06 This book is intended as a text for a first course in stochastic processes at the upper undergraduate or graduate levels assuming only that the reader has had a serious calculus course advanced calculus would even be better as well as a first course in probability without measure theory In guiding the student from the simplest classical models to some of the spatial models currently the object of considerable research the text is aimed at a broad audience of students in biology engineering mathematics and physics The first two chapters deal with discrete Markov chains recurrence and transience random walks birth and death chains ruin problem and branching processes and their stationary distributions These classical topics are treated with a modern twist in particular the coupling technique is introduced in the first chapter and is used throughout The third chapter deals with continuous time Markov chains Poisson process queues birth and death chains stationary distributions The second half of the book treats spatial processes This is the main difference between this work and the many others on stochastic processes Spatial stochastic processes are rightly known as being difficult to analyze The few existing books on the subject are technically challenging and intended for a mathematically sophisticated reader We picked several interesting models percolation cellular automata branching random walks contact process on a tree and concentrated on those properties that can be analyzed using elementary methods

**Applications of Linear and Nonlinear Models** Erik Grafarend, Joseph L. Awange, 2012-08-15 Here

we present a nearly complete treatment of the Grand Universe of linear and weakly nonlinear regression models within the first 8 chapters Our point of view is both an algebraic view as well as a stochastic one For example there is an equivalent lemma between a best linear uniformly unbiased estimation BLUE in a Gauss Markov model and a least squares solution LESS in a system of linear equations While BLUE is a stochastic regression model LESS is an algebraic solution In the first six chapters we concentrate on underdetermined and overdetermined linear systems as well as systems with a datum defect We review estimators algebraic solutions of type MINOLESS BLIMBE BLUMBE BLUE BIQUE BLE BIQUE and Total Least Squares The highlight is the simultaneous determination of the first moment and the second central moment of a probability distribution in an inhomogeneous multilinear estimation by the so called E D correspondence as well as its Bayes design In addition we discuss continuous networks versus discrete networks use of Grassmann Pluecker coordinates criterion matrices of type Taylor Karman as well as FUZZY sets Chapter seven is a speciality in the treatment of an overdetermined system of nonlinear equations on curved manifolds The von Mises Fisher distribution is characteristic for circular or hyper spherical data Our last chapter eight is devoted to probabilistic regression the special Gauss Markov model with random effects leading to estimators of type BLIP and VIP including Bayesian estimation A great part of the work is presented in four Appendices Appendix A is a treatment of tensor algebra namely linear algebra matrix algebra and multilinear algebra Appendix B is devoted to sampling distributions and their use in terms of confidence intervals and confidence regions Appendix C reviews the elementary notions of statistics namely random events and stochastic processes Appendix D introduces the basics of Groebner basis algebra its careful definition the Buchberger Algorithm especially the C F Gauss combinatorial algorithm

**Crystal Engineering Through Particle Size and Shape Monitoring, Modeling, and Control** Daniel B. Patience,2002 **The Journal of Chemical Physics** ,1994 The Publishers Weekly ,1972 **The Recovery of Polymer Melts After Shear and Elongational Flows** Ulrik Borghjerg,1994 *Mathematical Reviews* ,1993 **Probing the Structure of Bulk Polymers and Alloys Using Electronic Excitation Transport** Andrew H. Marcus,1994 **Neurobehavioral Toxicology** Zoltan Annau,1986 **Behavioral Incentives, Equilibrium Endemic Disease, and Health Management Policy for Farmed Animals** David A. Hennessy,2005 **English Mechanic and World of Science** ,1873 *Choice* ,1993

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