

Bibliography

1. Abramson, N. M., *Information Theory and Coding*, McGraw-Hill, New York, 1963.
2. Alexander, S. T., *Adaptive Signal Processing: Theory and Applications*, Springer-Verlag, New York, 1986.
3. Andrews, H. C., and B. R. Hunt, *Digital Image Restoration*, Prentice-Hall, Englewood Cliffs, NJ, 1977.
4. Asmussen, S., *Applied Probability and Queues*, Wiley, New York, 1987.
5. Bartlett, M. S., *An Introduction to Stochastic Processes with Special Reference to Methods and Applications*, 3rd ed., Cambridge University Press, London, 1978.
6. Bailey, N. T. J., *The Elements of Stochastic Processes with Applications to the Natural Sciences*, Wiley, New York, 1964.
7. Bellanger, M., *Adaptive Digital Filters and Signal Analysis*, Marcel Dekker, New York, 1987.
8. Besag, J., Spatial interaction and the statistical analysis of lattice systems, *J. Royal Statistical Society B*, **36**(1974).
9. Bharucha-Reid, A. T., *Elements of the Theory of Markov Processes and Their Applications*, McGraw-Hill, New York, 1960.
10. Bhat, U. N., *Elements of Applied Stochastic Processes*, Wiley, New York, 1972.
11. Bhattacharya, R. N., *Stochastic Processes with Applications*, Wiley, New York, 1990.
12. Bishop, C. M., *Neural Networks for Pattern Recognition*, Clarendon Press, Oxford, UK, 1995.
13. Bouleau, N., and D. Lepingue, *Numerical Methods for Stochastic Processes*, Wiley, New York, 1993.
14. Boullion, T. L., and P. L. Odell, *Generalized Inverse Matrices*, Wiley-Interscience, New York, 1971.
15. Bow, S.-T., *Pattern Recognition and Image Preprocessing*, Marcel Dekker, New York, 1992.
16. Bracewell, R. N., *Two Dimensional Imaging*, Prentice-Hall, Englewood Cliffs, NJ, 1995.
17. Bucy, R. S., and P. D. Joseph, *Filtering for Stochastic Processes with Applications to Guidance*, Interscience Publishers, New York, 1968.
18. Catlin, D. E., *Estimation, Control, and the Discrete Kalman Filter*, Springer-Verlag, Berlin, 1989.
19. Chellappa, R., *Digital Image Processing*, rev. ed., IEEE Computer Society Press, Los Alamitos, California, 1992.
20. Chui, C. K., and G. Chen, *Kalman Filtering*, Springer-Verlag, New York, 1987.

21. Choquet, G., "Theory of capacities," *Annals Institute Fourier*, V(1953–54).
22. Clarke, R. J., *Transform Coding of Images*, Academic Press, New York, 1985.
23. Cooper, G. R., and C. D. McGillem, *Probabilistic Methods of Signal and System Analysis*, Holt, Rinehart and Winston, New York, 1971.
24. Cowan, C. F., and P. M. Grant, *Adaptive Filters*, Prentice-Hall, Englewood Cliffs, NJ, 1985.
25. Cox, D. R., and H. D. Miller, *The Theory of Stochastic Processes*, Methuen, London, 1968.
26. Cramér, H., *Mathematical Methods of Statistics*, Princeton University Press, Princeton, NJ, 1946.
27. Cramér, H., and M. R. Leadbetter, *Stationary and Related Stochastic Processes; Sample Function Properties and Their Applications*, Wiley, New York, 1967.
28. Cramér, H., *Random Variables and Probability Distributions*, 3rd ed., Cambridge University Press, London, 1970.
29. Cramér, H., "Contributions to the theory of statistical estimation," *Skandinavisk Aktuarietidskrift*, 1946.
30. Cressie, N., *Statistics for Spatial Data*, Wiley, New York, 1991.
31. Cressie, N., and G. M. Lasslett, "Random set theory and problems of modeling, *SIAM Review*, 29, No. 4(1987).
32. Davenport, W. B., Jr., and W. L. Root, *An Introduction to the Theory of Random Signals and Noise*, IEEE Press, New York, 1987.
33. Davenport, W. B., Jr., *Probability and Random Processes; an Introduction for Applied Scientists and Engineers*, McGraw-Hill, New York, 1970.
34. David, H. A., *Order Statistics*, Wiley, New York, 1970.
35. DeGroot, M. H., *Optimal Statistical Decisions*, McGraw-Hill, New York, 1970.
36. Devroye, L., Györfi, L., and G. Lugosi, *A Probabilistic Theory of Pattern Recognition*, Springer, New York, 1996.
37. Dobrushin, P. L., "The description of a random field by means of conditional probabilities and conditions of its regularity," *Theory of Probability and Its Applications*, 13, No. 2(1968).
38. Doob, L. J., *Stochastic Processes*, Wiley, New York, 1953.
39. Dougherty, E. R., ed., *Mathematical Morphology in Image Processing*, Marcel Dekker, New York, 1993.
40. Dougherty, E. R. *Probability and Statistics for the Engineering, Computing, and Physical Sciences*, Prentice-Hall, Englewood Cliffs, NJ, 1990.
41. Dougherty, E. R., and J. Astola, eds., *Nonlinear Image Filters*, SPIE Press and IEEE Press, Bellingham, WA, 1998.
42. Dougherty, E. R., and C. R. Giardina, *Image Processing—Continuous to Discrete*, Prentice-Hall, Englewood Cliffs, NJ, 1987.
43. Duda, R. O., and P. E. Hart, *Pattern Classification and Scene Analysis*, Wiley, New York, 1973.

44. Dunford, N., and J. T. Schwartz, *Linear Operators: Part I: General Theory*, Wiley, New York, 1976.
45. Einstein, A., *Investigations on the Theory of the Brownian Movement*, Dover, New York, 1956 (contains translations of Einstein's 1905 papers).
46. Feller, W., *An Introduction to Probability Theory and Its Applications*, Vol. 1, 3rd ed., Wiley, New York, 1968.
47. Feller, W., *An Introduction to Probability Theory and Its Applications*, Vol. 2, 2nd ed., Wiley, New York, 1971.
48. Freund, J. E., and R. E. Walpole, *Mathematical Statistics*, 4th ed., Prentice-Hall, Englewood Cliffs, NJ, 1987.
49. Fukunaga, K., *Introduction to Statistical Pattern Recognition*, Academic Press, New York, 1972.
50. Gelb, A., ed., *Applied Optimal Estimation*, MIT Press, Cambridge, MA, 1974.
51. Gelfand, I. M., and G. E. Shilov, *Generalized Functions*, Academic Press, New York, 1965.
52. Gnedenko, B. V., *The Theory of Probability*, 4th ed., Chelsea, New York, 1967.
53. Gonzalez, R. K., and R. E. Woods, *Digital Image Processing*, Addison-Wesley, Reading, PA, 1992.
54. Goffman, C., and G. Pedrick, *First Course in Functional Analysis*, Prentice-Hall, Englewood Cliffs, NJ, 1965.
55. Goldberg, R. R., *Fourier Transforms*, Cambridge University Press, Cambridge, MA, 1965.
56. Goutsias, J., "On the morphological analysis of random shapes," *Mathematical Imaging and Vision*, 2, No. 2/3(1992).
57. Hall, P., *Introduction to the Theory of Coverage Processes*, Wiley, New York, 1988.
58. Halmos, P. R., *Measure Theory*, Van Nostrand, Princeton, 1974.
59. Halmos, P. R., *Finite Dimensional Vector Spaces*, Van Nostrand, Princeton, 1958.
60. Haralick, R. M., and L. G. Shapiro, *Computer and Robot Vision*, Vols. 1 & 2, Addison-Wesley, Reading, PA, 1992.
61. Haykin, S., *Adaptive Filter Theory*, 2nd ed., Prentice-Hall, Englewood Cliffs, NJ, 1991.
62. Haykin, S., *Neural Networks*, Macmillan, New York, 1994.
63. Helstrom, C. W., *Statistical Theory of Signal Detection*, 2nd ed., Pergamon Press, New York, 1968.
64. Hoel, P. G., *Introduction to Mathematical Statistics*, 4th ed., Wiley, New York, 1971.
65. Hoel, P. G., S. C. Port, and C. J. Stone, *Introduction to Probability Theory*, Houghton Mifflin, Boston, MA, 1971.
66. Hoel, P. G., S. C. Port, and C. J. Stone, *Introduction to Statistical Theory*, Houghton Mifflin, Boston, MA, 1971.

67. Hoel, P. G., S. C. Port, and C. J. Stone, *Introduction to Stochastic Theory*, Houghton Mifflin, Boston, MA, 1972.
68. Hoffman, K., and R. Kunze, *Linear Algebra*, Prentice-Hall, Englewood Cliffs, NJ, 1971.
69. Hogg, R. V., and A.T. Craig, *Introduction to Mathematical Statistics*, 4th ed., Macmillan, New York, 1978.
70. Isaacson, D. L., and R. W. Madsen, *Markov Chains: Theory and Applications*, Wiley, New York, 1976.
71. Jain, A. K., *Fundamentals of Digital Image Processing*, Prentice-Hall, Englewood Cliffs, NJ, 1989.
72. Jenkins, G. M., and D. G. Watts, *Spectral Analysis and its Applications*, Holden-Day, San Francisco, CA, 1968.
73. Jeulin, D., ed., *Advances in Theory and Applications of Random Sets*, World Scientific, London, 1997.
74. Kalman, R. E., A New Approach to Linear Filtering and Prediction Problems, *Basic Engineering (ASME)*, **82D**, (1960).
75. Kalman, R. E., and R. Bucy, New Results in Linear Filtering and Prediction, *Basic Engineering (ASME)*, **83D**, (1961).
76. Karhunen, K., Uber lineare Methoden in der Wahrscheinlichkeitsrechnung, *Ann. Acad. Sci. Fennicae*, A I, No. 37(1947).
77. Kemeny, J., L. J. Snell and A. Knapp, *Denumerable Markov Chains*, 2nd ed., Springer-Verlag, New York, 1976.
78. Kemeny, J., and L. J. Snell, *Finite Markov Chains*, Springer-Verlag, New York, 1960.
79. Kendall, M. G., and P. A. P. Moran, *Geometrical Probability*, Griffin, London, 1963.
80. Kendall, M., and A. Stuart, *The Advanced Theory of Statistics*, 4th ed., Macmillan, New York, 1977-1983.
81. Khinchin, A. I., "Theory of correlation of stationary stochastic processes," *Uspek. mat. nauk*, 5 (1938).
82. Khinchin, A. I., *Mathematical Foundations of Information Theory*, Dover, New York, 1957.
83. Kleinrock, L., *Queuing Systems*, Vol. I: *Theory*, Wiley, New York, 1975.
84. Kleinrock, L., *Queuing Systems*, Vol. 2: *Computer Applications*, Wiley, New York, 1976.
85. Kolmogorov, A., "Stationary sequences in Hilbert space," *Bulletin Math. University Moscow* 2(1941).
86. Kolmogorov, A., "The interpolation and extrapolation of stationary random sequences," *Akad. nauk SSSR, ser. mat.*, 5, No. 1(1941).
87. Kolmogorov, A., *Foundations of the Theory of Probability*, 2nd ed., Chelsea, New York, 1956.
88. Kolmogorov, A., "Interpolation and extrapolation of stochastic random sequences," in *Linear Least-Squares Estimation*, T. Kailath, ed., Hutchinson and Ross, 1977.

89. Kreider, D. L., R. G. Kuller, D. R. Ostberg and F. W. Perkins, *An Introduction to Linear Analysis*, Addison-Wesley, Reading, PA, 1966.
90. Kuznetsov, P. I., V. I. Tikhonov, and R. L. Stratonovich, *Non-Linear Transformations of Stochastic Processes*, Pergamon Press, New York, 1965.
91. Lewis, F. L., *Optimal Estimation: With an Introduction to Stochastic Control Theory*, Wiley, New York, 1986.
92. Lewis, T. O., and P. L. Odell, *Estimation in Linear Models*, Prentice-Hall, Englewood Cliffs, NJ, 1971.
93. Lim, J. S., *Two-Dimensional Signal and Image Processing*, Prentice-Hall, Englewood Cliffs, NJ, 1990.
94. Loève, M., *Probability Theory I*, 4th ed., Springer-Verlag, New York, 1977.
95. Loève, M., *Probability Theory II*, 4th ed., Springer-Verlag, New York, 1978.
96. Loce, R. P., and E. R. Dougherty, *Enhancement and Restoration of Digital Documents: Statistical Design of Nonlinear Algorithms*, SPIE Press, Bellingham, WA, 1997.
97. Mardia, K. V., and G. K. Kanji, eds., *Statistics and Images*, Carfax Pub., Abingdon, Oxfordshire, UK, 1993.
98. Matheron, G., *Random Sets and Integral Geometry*, Wiley, New York, 1975.
99. Medhi, J., *Stochastic Processes*, 2nd ed., Wiley, New York, 1994.
100. Miller, K. S., *Multidimensional Gaussian Distributions*, Wiley, New York, 1964.
101. Molchanov, I. A., *Statistics of the Boolean Model for Practitioners and Mathematicians*, Wiley, Chichester, UK, 1997.
102. Morse, P., *Queues, Inventories and Maintenance: the Analysis of Operational Systems with Variable Demand and Supply*, Wiley, New York, 1958.
103. Netravali, A. N., and B. G. Haskell, *Digital Pictures: Representation and Compression*, Plenum Press, New York, 1988.
104. Oppenheim, A. V., and R. W. Schaffer, *Digital Signal Processing*, Prentice-Hall, Englewood Cliffs, NJ, 1975.
105. Oppenheim, A. V., A. S. Willsky, and I. T. Young, *Signals and Systems*, Prentice-Hall, Englewood Cliffs, NJ, 1983.
106. Papoulis, A., *Probability, Random Variables, and Stochastic Processes*, 2nd ed., McGraw-Hill, New York, 1984.
107. Parzen, E., *Modern Probability Theory and Its Applications*, Wiley, New York, 1960.
108. Parzen, E., *Stochastic Processes*, Holden-Day, San Francisco, CA, 1962.
109. Pitas, I., *Digital Image Processing Algorithms*, Prentice-Hall, New York, 1993.
110. Poor, H. V., *An Introduction to Signal Detection and Estimation*, 2nd, Springer-Verlag, Berlin, 1994.
111. Pratt, W. K., *Digital Image Processing*, 2nd, Wiley, New York, 1991.
112. Preston, C. J., *Random Fields*, Springer-Verlag, New York, 1976.

113. Prokhorov, V. S., *Probability Theory: Basic Concepts, Limit Theorems, Random Processes*, Springer-Verlag, New York, 1969.
114. Pugachev, V. S., *Theory of Random Functions and Its Applications to Control Problems*, Pergamon Press, Oxford, (U.S. ed. distributed by Addison-Wesley, Reading, MA), 1965.
115. Pugachev, V. S., "The application of canonical expansions of random functions to the determination of the optimal linear system," *Avtomat. i telemekh.*, **27**, No. 6(1956).
116. Pugachev, V. S., "Integral canonical representations of random functions and their application to the determination of optimal linear systems," *Avtomat. i telemekh.*, **28**, No. 11(1957).
117. Rabbani, M., and P. W. Jones, *Digital Image Compression Techniques*, SPIE Press, Bellingham, WA, 1991.
118. Rao, C. R., *Linear Statistical Inference and Its Applications*, 2nd ed., Wiley, New York, 1973.
119. Rosenblatt, M., *Random Processes*, 2nd ed., Springer-Verlag, New York, 1974.
120. Rosenfeld, A., and A. C. Kak, *Digital Picture Processing*, Vols. 1 & 2, Academic Press, New York, 1982.
121. Ross, S. M., *A First Course in Probability*, 4th ed., Macmillan, New York, 1994.
122. Ross, S. M., *Stochastic Processes*, Wiley, New York, 1983.
123. Rozanov, Y. A., *Introductory Probability Theory*, Prentice-Hall, Englewood Cliffs, NJ, 1969.
124. Rozanov, Y. A., *Innovation Processes*, Wiley, New York, 1977.
125. Rubinstein, R., *Simulation and the Monte Carlo Method*, Wiley, New York, 1981.
126. Rudin, W., *Real and Complex Analysis*, McGraw-Hill, New York, 1966.
127. Rudin, W., *Functional Analysis*, McGraw-Hill, New York, 1973.
128. Ruiz-Pala, E., C. Avila-Beloso and W. W. Hines, *Waiting-Line Models; an Introduction to Their Theory and Applications*, Reinhold, New York, 1967.
129. Rumelhart, D. E., and J. L. McClelland, eds, *Parallel Distributed Processing: Explorations in the Microstructure of Cognition*, Vol. 1, MIT Press, Cambridge, MA, 1986.
130. Ruymgaart, P. A., and T. T. Soong, *Mathematics of Kalman-Bucy Filtering*, Springer-Verlag, Berlin, 1985.
131. Santalo, L. A., *Integral Geometry and Geometric Probability*, Addison-Wesley, Reading, PA, 1978.
132. Semenov, V. M., "A contribution to the extrapolation of random time series," *Sborn. VVIA im. Zhukovskogo*, **1** (1954).
133. Serra, J., *Image Analysis and Mathematical Morphology*, Academic Press, London, 1982.
134. Serra, J., ed., *Image Analysis and Mathematical Morphology*, Vol. 2, Academic Press, New York, 1988.

135. Shannon, C. E., "A mathematical theory of communication," *Bell Systems Technical Journal*, 27 (1948).
136. Sklansky, J., and G. N. Wassel, *Pattern Classifiers and Trainable Machines*, Springer-Verlag, New York, 1981.
137. Stark, H., and J. W. Woods, *Probability, Random Processes, and Estimation Theory for Engineers*, Prentice-Hall, Englewood Cliffs, NJ, 1986.
138. Stewart, J. W., ed., *Numerical Solutions of Markov Chains*, Marcel Dekker, New York, 1991.
139. Stoyan, D., and W. S. Kendall, *Stochastic Geometry and Its Applications*, Wiley, New York, 1987.
140. Taylor, H. M., and K. Samuel, *An Introduction to Stochastic Modeling*, Academic Press, Cambridge, MA, 1994.
141. Wald, A., *Sequential Analysis*, Dover Publications, New York, 1973.
142. Weeks, A. R., *Fundamentals of Electronic Image Processing*, SPIE Press and IEEE Press, Bellingham, WA, 1996.
143. Wegman, E. J., and D. J. DePriest, *Statistical Image Processing and Graphics*, Marcel Dekker, New York, 1986.
144. White, H., *Artificial Neural Networks: Approximation and Learning Theory*, Blackwell, Cambridge, UK, 1992.
145. Widrow, B., and S. D. Stearns, *Adaptive Signal Processing*, Prentice-Hall, Englewood Cliffs, NJ, 1985.
146. Wiener, N., "Generalized Harmonic Analysis," *Acta Math.*, 55(1930).
147. Wiener, N., *Nonlinear Problems in Random Theory*, Wiley, New York, 1958.
148. Wiener, N., *Extrapolation, Interpolation and Smoothing of Stationary Time Series*, MIT Press, Cambridge, MA, 1964.
149. Wong, E., and B. Hajek, *Stochastic Processes in Engineering Systems*, Springer-Verlag, New York, 1985.
150. Yaglom, A. M., *Stationary Random Functions*, Prentice-Hall, Englewood Cliffs, NJ, 1962.
151. Yosida, K., *Functional Analysis*, Springer-Verlag, New York, 1968.

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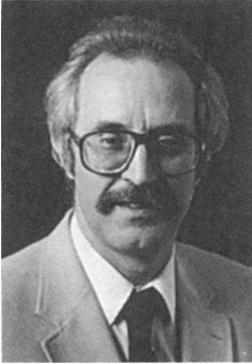
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Edward R. Dougherty is director of the Imaging Division of the Texas Center for Applied Technology and professor of Electrical Engineering at Texas A&M University. He holds an MS in computer science from Stevens Institute of Technology and a PhD in mathematics from Rutgers University. He is author of ten books, an editor of two books on image processing, and has written numerous papers on nonlinear image processing. He currently is Editor of the SPIE/IS&T *Journal of Electronic Imaging* and the SPIE/IEEE Series on Imaging Science and Engineering.