

References

- [A03] R.A. Adams, *Sobolev Spaces*, 2nd edn. (Academic, Amsterdam/Boston, 2003)
- [BC09] A. Bain, D. Crisan, *Fundamentals of Stochastic Filtering* (Springer, New York/London, 2009)
- [Be52] R. Bellman, On the theory of dynamic programming. Proc. Nat. Sci. U.S.A. **38**, 716–719 (1952)
- [Be57] R. Bellman, *Dynamic Programming* (Princeton University Press, Princeton, 1957)
- [Be75] V.E. Benes, Composition and invariance methods for solving some stochastic control problems. Adv. Appl. Prob. **7**, 299–329 (1975)
- [BSW80] V.E. Venes, L.A. Shepp, H.S. Witsenhausen, Some solvable stochastic control problems. Stochastics **4**, 39–83 (1980)
- [Be92] A. Bensoussan, *Stochastic Control of Partially Observable Systems* (Cambridge University Press, Cambridge/New York, 1992)
- [BN90] A. Bensoussan, M. Nisio, Nonlinear semigroup arising in the control of diffusions with partial observation. Stoch. Stoch. Rep. **30**, 1–45 (1990)
- [BP99] T.R. Bielecki, S.R. Pliska, Risk sensitive dynamic asset management. Appl. Math. Optim. **39**, 337–366 (1999)
- [BS73] F. Black, M. Scholes, The pricing of options and corporate liabilities. J. Polit. Econ. **81**, 637–659 (1973)
- [BM07] R. Buckdahn, J. Ma, Pathwise stochastic control problems and stochastic HJB equations. SIAM J. Control Optim. **45**, 2224–2256 (2007)
- [Br06] S. Brendle, Portfolio selection under incomplete information. Stoch. Proc. Appl. **116**, 701–723 (2006)
- [CPY09] M.H. Chng, T. Pang, J. Yong, Optimal stopping problem for stochastic differential equations with random coefficients. SIAM J. Control Optim. **48**, 941–971 (2009)
- [CI90] M.G. Crandall, H. Ishii, The maximum principle for semicontinuous functions. Differ. Integral Equ. **3**, 1001–1014 (1990)
- [CIL92] M.G. Crandall, H. Ishii, P.L. Lions, A user’s guide to viscosity solutions. Bull. AMS NS **27**, 1–67 (1992)
- [DaPZ92] G. Da Prato, J. Zabczyk, *Stochastic Equations in Infinite Dimensions* (Cambridge University Press, Cambridge, 1992)
- [ElKPQ97] N. El Karoui, S. Peng, M.C. Quenez, Backward stochastic differential equations in finance. Math. Finance **7**, 1–71 (1997)
- [ElKQ95] N. El Karoui, M.C. Quenez, Dynamic programming and pricing of contingent claims in an incomplete market. SIAM. J. Control Optim. **33**, 29–66 (1995)

- [E83] L.C. Evans, Classical solutions of Hamilton-Jacobi-Bellman equation for uniformly elliptic operators. *Trans. AMS* **275**, 245–255 (1983)
- [E98] L.C. Evans, *Partial Differential Equations*. GSM19 (AMS, Providence, 1998)
- [FH11] W.H. Fleming, D. Hernandez-Hernandez, On the value of stochastic differential games. *Commun. Stoch. Anal.* **5**, 341–351 (2011)
- [FKSh10] W.H. Fleming, H. Kaise, S.J. Sheu, Max-plus stochastic control and risk sensitivity. *Appl. Math. Optim* **62**, 81–144 (2010)
- [FMcE95] W.H. Fleming, W.H. McEneaney, Risk sensitive control on infinite time horizon. *SIAM J. Control Optim.* **33**, 1881–1915 (1995)
- [FR75] W.H. Fleming, R.W. Rishel, *Deterministic and Stochastic Optimal Control* (Springer, Berlin/New York, 1975)
- [FSh99] W.H. Fleming, S.J. Sheu, Optimal long term growth rate of expected utility of wealth. *Ann. Appl. Prob.* **9**, 871–903 (1999)
- [FSh00] W.H. Fleming, S.J. Sheu, Risk sensitive control and an optimal investment model. *Math. Finance* **10**, 197–213 (2000)
- [FSh02] W.H. Fleming, S.J. Sheu, Risk sensitive control and an optimal investment model II. *Ann. Appl. Prob.* **12**, 730–767 (2002)
- [FS06] W.H. Fleming, H.M. Soner, *Controlled Markov Processes and Viscosity Solutions*, 2nd edn. (Springer, New York 2006)
- [FS08] W.H. Fleming, P.E. Souganidis, On the existence of value function of two-player, zero-sum stochastic differential games. *Indiana Math. J.* **38**, 293–314 (1989)
- [FKK72] M. Fujisaki, G. Kallianpur, H. Kunita, Stochastic differential equations for the nonlinear filtering problem. *Osaka J. Math.* **9**, 19–40 (1972)
- [GŚ00] F. Gozzi, A. Świech, Hamilton-Jacobi-bellman equations for the optimal control of the Duncan-Mortensen-Zakai equation. *J. Funct. Anal.* **172**, 466–510 (2000)
- [HP81] J.M. Harrison, S.R. Pliska, Martingales and stochastic integrals in the theory of continuous trading. *Stoch. Proc. Appl.* **11**, 215–260 (1981)
- [HP83] J.M. Harrison, S.R. Pliska, Stochastic calculus model of continuous trading; complete markets. *Stoch. Proc. Appl.* **15**, 313–316 (1983)
- [HNSh10] H. Hata, H. Nagai, S.I. Sheu, Asymptotics of the probability minimizing a downside risk. *Ann. Appl. Prob.* **20**, 52–89 (2010)
- [HS10] H. Hata, J. Sekine, Explicit solution to a certain nonELQG risk-sensitive stochastic control problem. *Appl. Math. Optim.* **62**, 341–380 (2010)
- [IW81] N. Ikeda, S. Watanabe, *Stochastic Differential Equations and Diffusion Processes* (North Holland, Amsterdam/New York, 1981)
- [Is92] H. Ishii, Viscosity solutions for a class of Hamilton-Jacobi equations in Hilbert spaces. *J. Funct. Anal.* **105**, 301–341 (1992)
- [I42] K. Itô, Differential equations determining Markov processes. *Zenkoku Shijo Sugaku Danwakai* **244**, 1352–1400 (1942). (In Japanese)
- [I51] K. Itô, *On Stochastic Differential Equations*. *Memoirs of the American Mathematical Society*, vol. 4 (AMS, New York City, 1951)
- [JLL90] P. Jaillet, D. Lamberton, B. Lapeyer, Variational inequalities and the pricing of American options. *Acta Appl. Math.* **21**, 263–289 (1990)
- [KS91] I. Karatzas, S.E. Sheve, *Brownian Motion and Stochastic Calculus*, 2nd edn. (Springer, New York, 1991)
- [KS98] I. Karatzas, S.E. Sheve, *Methods of Mathematical Finance* (Springer, New York, 1998)
- [Ko04] S. Koike, *A Beginner's Guide to the Theory of Viscosity Solutions*. *MSJ Memoirs*, vol. 13 (JMS, Tokyo, 2004)
- [KN02] K. Kuroda, H. Nagai, Risk sensitive portfolio optimization and infinite time horizon. *Stoch. Stoch. Rep.* **73**, 309–331 (2002)
- [Kr09] N.V. Krylov, *Controlled Diffusion Processes*, 2nd edn. (Springer, Berlin, 2009)
- [Ku67] H.J. Kushner, Dynamical equations for optimal nonlinear filtering. *J. Differ. Equ.* **3**, 179–190 (1967)

- [La83] S. Lang, *Real Analysis*, 2nd edn. (Addison-Wesley, New York, 1983)
- [L83] P.L. Lions, Optimal control of diffusion processes and Hamilton-Jacobi-Bellman equations I. *J. Commun. PDE.* **8**, 1101–1134 (1983)
- [L88] P.L. Lions, Viscosity solutions of fully nonlinear second-order equations and optimal stochastic control in infinite dimensions. Part I. The case of bounded stochastic evolution. *Acta Math.* **161**, 243–278 (1988)
- [L89] P.L. Lions, Viscosity solutions of fully nonlinear second-order equations and optimal stochastic control in infinite dimensions. Part II. Optimal control of Zakai equation, in *Stochastic Partial Differential Equations and Applications II*, ed. by G. Da Prato, L. Tubaro. Lecture Notes in Mathematics, vol. 1390 (Springer, Berlin/Heidelberg, 1989), pp. 147–170. Part III. Uniqueness of viscosity solutions for general second order equations. *J. Funct. Anal.* **86**, 1–18 (1989)
- [LN83] P.L. Lions, M. Nisio, A uniqueness result for the semigroup associated with HJB equations. *Proc. Jpn. Acad.* **58**, 273–276 (1983)
- [LS01] R.S. Liptser, A.N. Shiriyayev, *Statistics of Random Processes I, II*, 2nd edn. (Springer, New York/Berlin, 2001)
- [Ma00] C. Martini, American option prices as unique viscosity solutions to degenerate HJB equations, Rapport de rech, INRIA, 2000
- [Me71] R.C. Merton, Optimal consumption and portfolio rules in continuous time. *J. Econ. Theory* **3**, 373–413 (1971)
- [Me73] R.C. Merton, Theory of rational option pricing. *Bell J. Econ. Manag. Sci.* **4**, 141–183 (1973)
- [M88] M. Metivier, *Stochastic Partial Differential Equations in Infinite Dimensional Spaces* (Scuola Superiore, Pisa, 1988)
- [My66] P.A. Meyer, *Probability and Potentials* (Blaisdell, Waltham, 1966)
- [Mo10] H. Morimoto, *Stochastic Control and Mathematical Modeling, Applications in Economics* (Cambridge University Press, Cambridge/New York, 2010)
- [Na03] H. Nagai, Optimal strategies for risk sensitive portfolio optimization problems for general factor models. *SIAM J. Control Optim.* **41**, 1779–1800 (2003)
- [N76] M. Nisio, On a nonlinear semigroup attached to stochastic optimal control. *Pull. RIMS* **12**, 513–537 (1976)
- [N78] M. Nisio, On nonlinear semigroups for Markov processes associated with optimal stopping. *Appl. Math. Optim.* **4**, 143–169 (1978)
- [N81] M. Nisio, *Lecture on Stochastic Control Theory*. ISI Lecture Notes, vol. 9 (McMillan India, Delhi 1981)
- [N88] M. Nisio, Stochastic differential games and viscosity solutions of Isaacs equations. *Nagoya Math. J.* **110**, 163–184 (1988)
- [P79] E. Pardoux, Stochastic partial differential equations and filtering of diffusion processes. *Stochastics* **3**, 127–167 (1979)
- [P93] E. Pardoux, Stochastic partial differential equations, a review. *Bull. Sc. Math.* **117**, 29–47 (1993)
- [PP90] E. Pardoux, S. Peng, Adapted solution of backward stochastic equation. *Syst. Control Lett.* **14**, 55–61 (1990)
- [Pe92] S. Peng, Stochastic Hamilton-Jacobi-Bellman equations. *SIAM J. Control Optim.* **30**, 284–304 (1992)
- [Ph02] H. Pham, Smooth solutions to optimal investment models with stochastic volatilities and portfolio constraints. *Appl. Math. Optim.* **46**, 55–78 (2002)
- [R90] B.L. Rozovskii, *Stochastic Evolution Systems* (Kluwer Academic, Dordrecht/Boston, 1990)
- [S08] A.N. Shiriyayev, *Optimal Stopping Rules*, 2nd edn. (Springer, Berlin/Heidelberg 2008)
- [St11] L. Stettner, Penalty method for finite horizon stopping problems. *SIAM J. Control Optim.* **49**, 1078–1099 (2011)

- [SV79] D.V. Strook, S.R.S. Varadhan, *Multidimensional Diffusion Processes* (Springer, Berlin/New York, 1979)
- [W71] J.C. Willems, Least squares stationary optimal control and the algebraic Riccati equation. *IEEE. Trans. Auto. Control* **16**, 621–635 (1971)
- [Wo68] W.M. Wonham, on a matrix Riccati equation of stochastic control. *SIAM J. Control Optim.* **6**, 681–697 (1968)
- [Y80] K. Yosida, *Functional Analysis*, 6th edn. (Springer, Berlin/New York, 1980)
- [YZ99] J. Yong, X.Y. Zhou, *Stochastic Controls, Hamiltonian Systems and HJB Equations* (Springer, New York, 1999)

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