# VITA

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**Orion Hoch Professor of Mathematics**
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## EDUCATION

**1973–1977 University of Illinois**
Urbana, Illinois
M.S. in Electrical Engineering
Ph.D. in Mathematics
Thesis advisor: Dmitri P. Bertsekas

**1972–1973 Georg-August-Universität**
Göttingen, Germany
Studied mathematics

**1968–1972 West Virginia University**
Morgantown, West Virginia
B.A. in German (*summa cum laude*)

## EMPLOYMENT

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|---|---|
| **Sept. 2006 – Present** | Orion Hoch Professsor of Mathematics, Carnegie Mellon University |
| **June 2005–July 2005** | Senior Visiting Fellow, Isaac Newton Institute for the Math. Sciences, University of Cambridge |
| **Sept. 1989 – Sept. 2006** | Prof. of Mathematics, Carnegie Mellon University |
| **May 1995 – June 1995** | Senior Visiting Fellow, Isaac Newton Institute for the Math. Sciences, University of Cambridge |
| **May 1991 – May 1994** | Assoc. Director, Carnegie Mellon Center for Nonlinear Analysis |
| **June 1982 – Aug. 1989** | Assoc. Prof. of Math., Carnegie Mellon University |
| **Sept. 1984 – May 1985** | Visiting Scientist, Lab. for Information and Decision Systems, Massachusetts Institute of Technology |
| **July 1980 – June 1982** | Assist. Prof. of Math., Carnegie Mellon University |

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| **Aug. 1978 – May 1980** | Assist. Prof. of Math., University of Delaware |
| **Sept. 1977 – July 1978** | Visiting Assist. Prof. of Math. and Stat., University of California at Berkeley |
| **Jan. 1977 – Aug. 1977** | Research Associate, Coordinated Science Laboratory University of Illinois |

## CARNEGIE MELLON PROGRAMS FOUNDED

Co-Founder, M.S. program in Computational Finance; Member of Steering Committee, 1993–present.

Founder, B.S. program in Computational Finance; Director, 2002–present.

Founder, Ph.D. program in Mathematical Finance; Director, 1992–2004.

Founder, Summer Undergraduate Mathematics Institute; Director, 1992–1996.

## HONORS

Author of *Stochastic Calculus for Finance II*, voted "Best New Book in Quantitative Finance" for 2004 by members of Wilmott website.

Doherty Prize, Carnegie Mellon Award for Sustained Contributions to Education, 2000.

Fellow, Institute of Mathematical Statistics

Phi Beta Kappa

## EDITORIAL BOARDS, ADVISORY BOARDS, ETC.

Scientific Organizing Committee, Seventh World Congress of Bachelier Society, Sydney, June 19–22, 2012.

Academic Program Review Committee, Georgia Inst. Tech., M.S. degree in Quantitative and Computational Finance, 2010.

President, Bachelier Finance Society, 2008–2009.

Past-President, Bachelier Finance Society, 2010–2011.

Vice-President, Bachelier Finance Society, 2006-2007.

Council of the Bachelier Finance Society, 2002-2005.

Member, Academic Review Committee, Dept. Operations Research and Financial Engineering, Princeton University, 2008.

Organizing Committee, Fourth World Congress of Bachelier Society, Tokyo, August 17–20, 2006.

Organizing Committee, "Developments in Quantitative Finance," Isaac Newton Institute, Cambridge, United Kingdom, Jan.–July, 2005.

Scientific Advisory Board of Frankfurt Mathematical Finance Institute, Frankfurt, Germany, 2003.

Associate Editor, *SIAM Journal on Financial Mathematics*, 2008–2011.

Associate Editor, *Annals of Applied Probability*, 2003–2005.

Advisory Editor, *Finance and Stochastics*, 2000–present.
Co-Editor, *Finance and Stochastics*, 1995–2000.
Associate Editor, *Stochastics and Stochastics Reports*, 1985–1988, 1993–present.
Book Review Editor, *Stochastics and Stochastics Reports*, 1988–1993.
Associate Managing Editor, *SIAM Journal on Control and Optimizaition*, 1988-1991.
Associate Editor, *SIAM Journal on Control and Optimization*, 1987–1988, 1992–1995.
Editor, *SIAM Journal on Control and Optimization*, special issue in honor of Wendell Fleming, 1993.
Associate Editor, *Annals of Probability*, 1982–1984.
Bernoulli Society Committee for Conferences on Stochastic Processes, 1995–2003.
Research Management Committee of the Canadian network on Mathematics of Information Technology and Complex Systems, 1999.
National Science Foundation site visit team to evaluate proposal for a Mathematical Sciences Research Institute, October 1998.
Organizing Committee for National Meeting of SIAM Activities Group in Control and Systems Theory, April 1995, St. Louis.
Organizing Committee for 1992-1993 Year on Control, Institute for Mathematics and its Applications, University of Minnesota. Organizer for the workshop and tutorial on mathematical finance, June 1993.
Panelist, National Association of Mathematicians Panel Discussion, "NAM's undergraduate MATHfest; one approach to the pipeline issue," Joint Mathematics Meetings, Cincinnati, 1994.
Panelist, Variations in Master's Programs in Financial Meathematics, AMS-MER-SIAM Workshop on Developing Professional Master's Degrees in Mathematics, New York University, November 1998.
Panelist, University-Industry Project Experience, SIAM Northeast Regional Mathematics in Industry Workshop, Worcester Polytechnic Institute, May 1998

## DOCTORAL STUDENTS

G. L. Xu: Dissertation: "A duality approach to a stochastic consumption/portfolio decision problem in a continuous time market with short-selling prohibition," May 1990. Director of Research, Guided Choice, La Jolla, CA.

D. Bridge: Dissertation: "Finite-fuel singular stochastic control of an

$n$-dimensional infinite-horizon discounted problem," Dec. 1991. Professor Emeritus, Mathematics and Statistics, University of Central Oklahoma.

B. Doytchinov: Dissertation: "Heavy traffic limits of queues with due dates," July 1997, Associate Professor of Mathematics, Elizabethtown College.

U. Wystup: Dissertation: "Value of exotic options under short-selling constraints as a singular stochastic control problem," Dec. 1997. Managing Directdor, MathFinance AG.

D. Wong: Dissertation: "A unifying credit model," May 1998. Senior Vice-President, Bank of America, Atlanta.

J. Večeř: Dissertation: "Options on a traded account," August 2000. Professor of Finance, Frankfurt School of Finance and Management.

D. Bunimovich: Dissertation: "Modeling and pricing of collateralized debt obligations," May 2002. Research scientist, Deutsche Bank, New York

M. Sîrbu: Dissertation: "A two-person game for pricing convertible bonds," May 2004. Associate Professor, Department of Mathematics, University of Texas at Austin.

M. Xu: Dissertation: "Minimizing shortfall risk using duality approach – An application to partial hedging in incomplete markets," May 2004. Associate Professor, Department of Mathematics, University of North Carolina at Charlotte.

K. Janeček: Dissertation: "Futures trading model with transactions, costs," August 2004. RSJ Invest, Prague, Czech Republic.

T. Pirvu: Dissertation: "Maximizing portfolio growth rate under risk constraints," April 2005. Assistant Professor, Department of Mathematics, McMaster University.

A. Karolik: Dissertation: "Modeling Correlated Credit Rating Migrations," February 2006. Research scientist, J.P. Morgan Chase, London.

M. Čudina: Dissertation: "Asymptotically optimal control for some time-varying stochastic networks," February 2007. Clinical Assistant Professor, University of Texas at Austin (co-advised with Kavita Ramanan).

G. Brunick: Dissertation: "A Weak Existence Result with Application to the Financial Engineer's Calibration Problem," July 2008. Post-doctoral Fellow, Department of Probability and Statistics, University of California, Santa Barbara.

M. Bichuch: Dissertation: "Asymptotic Analysis for Optimal Investment and Consumption with Transaction Costs with Two Futures Contracts," August 2010. Post-doctoral Fellow, Department of Operations Research and Financial Engineering, Princeton University.

## PUBLICATIONS

### Books:

**1.** D. P. Bertsekas and S. E. Shreve, *Stochastic Optimal Control: The Discrete Time Case*, Academic Press, New York, 1978, 323 pages. Russian translation by Nauka, 1985. Republished by Athena Scientific, Cambridge, MA, 1996.

**2.** I. Karatzas and S. E. Shreve, *Brownian Motion and Stochastic Calculus*, Springer-Verlag, New York, 1988, 470 pages. Chinese edition by Worldwide Publishing Co., 1990. Second edition by Springer-Verlag, 1991.

**3.** M. H. A. Davis, D. Duffie, W. Fleming and S. E. Shreve, editors, *Mathematical Finance*, IMA Volume 65, Springer-Verlag, New York, 1991.

**4.** I. Karatzas and S. E. Shreve, *Methods of Mathematical Finance*, Springer-Verlag, New York, 1998. Chinese edition by Beijing World Publishing Corporation, 2004.

**5.** S. E. Shreve, *Stochastic Calculus for Finance. Volume I – The Binomial Asset Pricing Model. Volume II – Continuous Time Models*, Springer-Verlag, New York, 2004.

**Articles in refereed journals:**

**1.** Alternative theoretical frameworks for finite horizon discrete-time stochstic optimal control, *SIAM J. Control and Optimization* 16 (1978), 953–978 (with D. P. Bertsekas).

**2.** Existence of optimal stationary policies in deterministic optimal control, *J. Math. Anal. Appl.* 69 (1979), 607–620 (with D. P. Bertsekas).

**3.** Universally measurable policies in dynamic programming, *Math. Operations Research* 4 (1979), 15–30 (with D. P. Bertsekas).

**4.** Probability and the C-sets of Selivanovskij, *Pac. J. Math.* 79 (1979), 189–196.

**5.** Strong consistency of a modified maximum likelihood estimator for controlled Markov chains, *J. Appl. Probab.* 17 (1980), 726–734 (with B. Doshi).

**6.** A note on optimal switching between two activities, *Naval Res. Logist. Quart.* 28 (1981), 185–190.

**7.** Borel-approachable functions, *Fund. Math.* 112 (1981), 17–24.

**8.** Reflected Brownian motion in the "bang-bang" control of Brownian drift, *SIAM J. Control and Optimization* 19 (1981), 469–478.

**9.** Optimal consumption and investment policies allowing consumption constraints and bankruptcy, *Math. Operations Research* 8 (1983), 613–636 (with J. Lehoczky and S. Sethi).

**10.** Optimal consumption for general diffusions with absorbing and reflecting barriers, *SIAM J. Control and Optimization* 22 (1984), 55–75 (with J. Lehoczky and D. Gaver).

**11** Trivariate density of Brownian motion, its local and occupation times, with application, *Ann. Probab.* 12 (1984), 819–828 (with I. Karatzas).

**12.** Connections between optimal stopping and singular stochastic control, Part I: Monotone follower problem, *SIAM J. Control and Optimization* 22 (1984), 856–877 (with I. Karatzas).

**13.** Connection between optimal stopping and singular stochastic control, Part II: Reflected follower problems, *SIAM J. Control and Optimization* 23 (1985), 433–451 (with I. Karatzas).

**14.** Absolutely continuous and singular stochastic control, *Stochastics* 17 (1986), 91–109 (with J. Lehoczky).

**15.** Explicit solution of a general consumption/investment problem, *Math. Operations Research* 11 (1986), 261–294 (with I. Karatzas, J. Lehoczky and S. Sethi).

**16.** Equivalent models for finite-fuel stochastic control, *Stochastics* 18 (1986), 245–276 (with I. Karatzas).

**17** A decomposition of the Brownian path, *Statistics and Probability Letters* (1987), 87–93 (with I. Karatzas).

**18.** Optimal portfolio and consumption decisions for a "small investor" on a finite horizon, *SIAM J. Control and Optimization* 25 (1987), 1557–1586 (with I. Karatzas and J. Lehoczky).

**19.** Regularity of the value function for a two-dimensional singular stochastic control problem, *SIAM J. Control and Optimization* 27 (1989), 876–907 (with H. M. Soner).

**20.** Existence and uniqueness of multi-agent equilibrium in a stochastic, dynamic consumption/investment model, *Math. Operations Research* 15 (1990), 80–128 (with I. Karatzas and J. Lehoczky).

**21.** Martingale and duality methods for utility maximization in an incomplete market, *SIAM J. Control and Optimization* 29 (1991), 707–730 (with I. Karatzas, J. Lehoczky and G.-L. Xu).

**22.** A free boundary problem related to singular stochastic control: the parabolic case, *Comm. Partial Differential Equations* 16 (1991), 373–424 (with H. M. Soner).

**23.** Optimal investment and consumption with two bonds and transaction costs, *Math. Finance* 1 (1991), 53–84 (with H. M. Soner and G.-L. Xu).

**24.** Equilibrium models with singular asset prices, *Math. Finance* 1 (1991), 11–29 (with I. Karatzas and J. Lehoczky).

**25.** A duality method for optimal consumption and investment under short-selling prohibition, Part I: General market coefficients, *Ann. Appl. Probab.* 2 (1992), 87–112 (with G.-L. Xu).

**26.** A duality method for optimal consumption and investment under short-selling prohibition, Part II: Constant market coefficients, *Ann. Appl. Probab* 2 (1992), 314–328 (with G.-L. Xu).

**27.** Optimal investment and consumption with transaction costs, *Ann. Appl. Probab.* 4 (1994), 609–692 (with H. M. Soner).

**28.** Sensitivity of the indirect utility to transaction costs in a consumption-based model, *Ann. Appl. Probab.* 4 (1994), 680–689 (Appendix to 27).

**29.** There is no nontrivial hedging portfolio for option pricing with transaction costs, *Ann. Appl. Probab.* 5 (1995), 327–355 (with H. M. Soner and J. Cvitanić).

**30.** Heavy traffic convergence of a controlled, multi-class queueing system, *SIAM J. Control and Optimization* 34 (1996), 2133–2171 (with L. F. Martins and H. M. Soner).

**31.** Robustness of the Black and Scholes formula, *Math. Finance* 8 (1998), 93–126 (with N. El Karoui and M. Jeanblanc-Picqué).

**32.** Options on a traded account: vacation calls, vacation puts and passport options, *Finance and Stochastics* **4** (2000), 255–274 (with J. Večeř).

**33.** Upgrading your passport, RISK, July 2000, 81–83 (with J. Večeř).

**34.** Real-time queues in heavy traffic with earliest-deadline-first queue discipline, *Annals of Applied Probability* **11** (2001), 332–378. (with B. Doytchinov and J. Lehoczky).

**35.** Valuation of exotic options under shortselling constraints, *Finance and Stochastics* **6** (2002), 143–172 (with U. Schmock and U. Wystup).

**36.** Multiple-input heavy-traffic real-time queues, *Annals of Applied Probability* 13 (2003), 54–99 (with L. Kruk, J. Lehoczky and S.-N. Yeung).

**37.** A general framework for pricing credit risk, *Mathematical Finance* 14 (2004), 317-350 (with A. Bélanger and D. Wong).

**38.** Earliest-deadline-first service in heavy-traffic acyclic networks, *Annals of Applied Probability* 14 (2004), 1306–1352 (with L. Kruk, J. Lehoczky and S.N. Yeung).

**39.** Asymptotic analysis for optimal investment and consumption with transaction costs, *Finance and Stochastics* **8** (2004), 181–206 (with K. Janeček).

**40.** Perpetual convertible bonds, *SIAM J. Control Optimization* **43** (2005), 58–85 (with M. Sîrbu and I. Pikovsky).

**41.** Satisfying convex risk limits by trading, *Finance and Stochastics* **9** (2005), 177–196 (with K. Larsen, T. Pirvu and R. Tütüncü).

**42.** Accuracy of state space collapse for earliest-deadline-first queues, *Annals of Applied Probability* **16** (2006), 516–581 (with Ł. Kruk and J. Lehoczky).

**43.** A two-person game for pricing convertible bonds, *SIAM J. Control Optimization* **45** (2006), 1508–1639 (with M. Sîrbu).

**44.** An explicit formula for the Skorohod map on $[0, a]$, *Annals of Probability* **35** (2007), 1740–1768 (with Ł. Kruk, J. Lehoczky and K. Ramanan).

**45.** Heavy traffic analysis for EDF queues with reneging, *Annals of Applied Probabilty* **21** (2011), 484–545 (with Ł. Kruk, J. Lehoczky and K. Ramanan).

**46.** Futures trading with transaction costs, to appear *Illinois J. Mathematics* (with K. Janeček).

**47.** Optimal execution in a general one-sided limit-order book, *SIAM J. Financial Math* **2** (2011), 183—212 (with S. Predoiu and G. Shaikhet).

**48.** Mimicking an Itô process by a solution of a stochastic differential equation, *Annals of Applied Probability*, to appear.

**Conference proceedings papers and articles in books:**

**1.** A new theoretical framework for finite-horizon stochastic optimal control, Proc. Fourteenth Allerton Conf. on Circuit and System Theory, Allerton Park, IL, 1976, 336–343 (with D. P. Bertsekas).

**2.** Equivalent stochastic and deterministic optimal control problems, Proc. 1976 IEEE Conf. on Decision and Control, Clearwater Beach, FL, 705–709 (with D. P. Bertsekas).

**3.** Alternative theoretical frameworks for finite horizon discrete-time stochastic optimal control, Proc. 1977 IEEE Conf. on Decision and Control, New Orleans, LA (with D. P. Bertsekas).

**4.** Dynamic programming in Borel spaces, Proc. International Conf. on Dynamic Programming, Vancouver, Canada, 1977, Academic Press, New York (with D. P. Bertsekas).

**5.** On the theory of dynamic programming and stochastic optimal control, Proc. 1978 ORSA/TIMS meeting, New York (with D. P. Bertsekas).

**6.** Resolution of measurability problems in discrete-time stochastic control, Proc. Workshop on Stochastic Control Theory and Stochastic Differential Systems, Bad Honnef, Germany, 1979, M. Kohlmann, ed., Springer-Verlag, Heidelberg.

**7.** A martingale formulation for optimal consumption/investment decision making, in Optimal Control Theory and Economic Analyses 2, Proc. Second Viennese Workshop on Economic Applications of Control Theory, G. Feichtinger, ed., North-Holland, Amsterdam, 198 (with J. Lehoczky and S. Sethi).

**8.** Explicit solution of a consumption/investment problem, in Lecture Notes on Control and Information Sciences, V. I. Arkin, A. Shiryayev and R. Wets, ed., Springer-Verlag, New York, 1986 (with I. Karatzas, J. Lehoczky and S. Sethi).

**9.** Explicit solution of a general consumption/investment problem, Proc. Third Bad Honnef Conf. on Stochastic Differential Systems, Bad Honnef, Germany, 1985, K. Helmes, ed., Springer-Verlag, New York.

**10.** An introduction to singular stochastic control, Proc. Workshop on Stochastic Differential Systems, Stochastic Control Theory, and Applications, Institute for Mathematics and its Applications, Vol. 10, W. Fleming, and P. L. Lions, eds., Springer-Verlag, New York, 1988.

**11.** A free boundary problem related to singular stochastic control, Proc. 1989 Imperial College Workshop on Applied Stochastic Analysis, M. H. A. Davis and J. M. C. Clark, eds., Gordon and Breach, London (with H. M. Soner).

**12.** A control theorist's view of asset pricing, Proc. 1989 Imperial College Workshop on Applied Stochastic Analysis, M. H. A. Davis and J. M. C. Clark, eds., Gordon and Breach, London.

**13.** Equilibrium in a simplified dynamic stochastic economy with heterogeneous agents, in Stochastic Analysis: Liber Amicorum for Moshe Zakai, (Proc. of Conf. in Honor of Moshe Zakai, Technion, Haifa, 1991), 245–272, Academic Press, Orlando (with P. Lakner, I. Karatzas and J. Lehoczky).

**14.** Multi-dimensional finite-fuel stochastic control, Lecture Notes in Control and Information Sciences 177 (Applied Stochastic Analysis), Proc. U.S.-French Workshop on Applied Stochastic Analysis, Rutgers, New Brunswick, 1991, Springer-Verlag, New York, 38-58 (with D. Bridge).

**15.** Martingales and the theory of capital asset pricing, Lecture Notes in Control and Information Sciences 180 (System Modeling and Optimization), Proc. 15th I.F.I.P. Conf., Zürich, Sept. 1991, Springer-Verlag, Berlin, 809–823.

**16.** Liquidity premium for capital asset pricing with transaction costs, IMA Volumes in Mathematics and its Applications 65 (Mathematical Finance), Proc. Workshop on Mathematical Finance, Minneapolis, June 1993, Springer-Verlag, New York.

**17.** Quantitative methods for portfolio management, AMS Short Course, San Diego, January, 1977. In *Introduction to Mathematical Finance*, Proc. Symposia Applied Mathematics, Vol. 57, American Math. Soc., Providence, RI, 1999.

**18.** Dealing with dangerous digitals, in *Foreign Exchange Risk*, Risk Publications, London, 2002, 327–348 (with U. Schmock and U. Wystup).

**19.** Second order approximation for the customer time in queue distribution under the FIFO service discipline, *Annales Universitatis Mariae Curie-Skłodowska, Sectio AI: Informatica* **1**, 37–48, 2003 (with Ł. Kruk and J. P. Lehoczky).

**20.** Double Skorokhod map and reneging real-time queues, in *Markov Processes and Related Topics: A Festschrift for Thomas G. Kurtz*, S. Ethier, J. Feng and R. Stockbridge, eds., Institute of Mathematical Statistics Collections, Vol. 4, pp. 169–193, 2008 (with Ł. Kruk, J. Lehoczky and K. Ramanan).