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Optimization, Control, and Applications of Stochastic Systems

In Honor of Onésimo Hernández-Lerma

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Onesimo Hernández-Lerma, Mexico City, 2011

Foreword

Professor Onésimo Hernández-Lerma has made a great number of fundamental contributions in the field of stochastic control systems during the last 30 years. He has contributed to the development of this theory in many aspects, which include adaptive control, parametric estimation, recursive algorithms, infinite dimensional linear programming, ergodic properties of Markov processes, measure theory, discrete- and continuous-time controlled Markov processes, and game theory. Also, his research work has been concerned with important applications to the areas of queuing systems, control of population, and management sciences.

He has authored more than 140 papers, some of which still have a great influence in the study of controlled stochastic systems, since he was the first to mathematically formalize many fundamental results. He recently received the Scopus Prize (2008) and the Thomson Reuters Award (2009), recognizing the influence and importance of his work.

Professor Hernández-Lerma has written or coauthored 11 books or monographs on different topics. In the field of stochastic control, his book *Adaptive Markov Control Processes* (1989) soon became a reference for researchers and graduate students, and today it is considered a classic. In 1996 and 1999 he jointly wrote with J. B. Lasserre the books *Discrete-Time Markov Control Processes: Basic Optimality Criteria* and *Further Topics on Discrete-Time Markov Control Processes*, giving a systematic and deep study to controlled Markov processes on Borel spaces with several optimality criteria. The techniques required to deal with discrete- and continuous-time models are different, but in many aspects the general intuition from one can be applied to the other. This intuition was firmly grounded in his most recent books *Continuous-Time Markov Decision Processes: Theory and Applications* (with X. P. Guo) and *Selected Topics on Continuous-Time Controlled Markov Chains and Markov Games* (with T. Prieto-Rumeau).

Among the diverse optimality criteria analyzed in the work of Professor Hernández-Lerma, one of the most important is the *average* or *ergodic* index, where the asymptotic behavior of the controlled stochastic process needs to be well understood to verify the existence of solutions of the optimal control problem and to characterize the value function in terms of the optimality equation. The book

Markov Chains and Invariant Probabilities, written jointly with J. B. Lasserre and published in 2003, is precisely a well-established work on the ergodic behavior of Markov chains in metric spaces. Average optimality represents an interesting combination of ergodic theory and stochastic optimal control and requires effective techniques and clever ideas to deal with problems from adaptive control, partially observed processes, linear programming and approximating procedures, among others, and on this topic we can find a good number of papers by Professor Hernández-Lerma. A complete list of his publications is given below.

Professor Hernández-Lerma received his Ph.D. from Brown University in 1978, and since then he has been a regular faculty member of the Mathematics Department at the Centro de Investigación y de Estudios Avanzados (Cinvestav) of the Instituto Politécnico Nacional, where he has carried out most of his research and teaching activities. His work had a pioneering character in Mexico, where he was the first expert in stochastic control. Groups of mathematicians in Mexico were quite small in those years and only few people could see the potential of having a strong group in the field of stochastic optimal control.

At Cinvestav he has always been recognized by his students for his excellent ability to lecture on many topics such as real analysis, probability theory, Markov processes, and stochastic calculus. Up to now he has graduated 17 Ph.D. students, a record among Mexican mathematicians, and his former students recognize his generosity, sensitivity, and his ability to propose cutting-edge research projects. The results of most of those Ph.D. theses have been published in well-established international journals. Since 1986 he has regularly organized the Workshop on Stochastic Control, which is an important forum for the group of stochastic control in Mexico to present new research and to interact with experts from other countries. This group has an intense research activity thanks to the inspiration of Professor Hernández-Lerma, who has also influenced a significant number of other young mathematicians and visiting postdoctoral fellows who have visited Cinvestav in these years.

He has participated in numerous editorial boards, for journals like the SIAM Journal on Control and Optimization, International Journal on Stochastic Analysis, and Journal of Dynamics and Games. He has also served as a guest editor of special volumes in top journals. Additionally, Professor Hernández-Lerma has always showed a genuine interest in probability and statistics education in Mexico and has written two monographs in on these topics.

The contributions of Professor Hernández-Lerma to the development of applied mathematics in his country were recognized by the Government of Mexico in 2001, when he received the Sciences and Arts National Award, being the third mathematician to obtain such a high distinction. Also, in 2003 he received a *doctor honoris causa* from the Universidad de Sonora, and in 2008 he was honored with the Medalla Lázaro Cárdenas by the Instituto Politécnico Nacional.

Guanajuato, México — Daniel Hernández-Hernández
Guanajuato, México — J. Adolfo Minjárez-Sosa

Preface

This volume presents a collection of papers by friends and colleagues of Professor Onésimo Hernández-Lerma in his honor. The first idea to compile the book arose during Onésimo's Fest Symposium held in San Luis Potosí, Mexico, during March 16–18, 2011, to honor the 65th birthday of Professor Onésimo Hernández-Lerma, who has been an important contributor to stochastic optimal control.

Thereafter, a group of colleagues whose research interests are in the areas of stochastic optimal control, optimization theory, and probability were invited to collaborate on this project. As a result, 33 authors from all over the world have contributed 18 chapters to the book. All papers have been peer-reviewed and give a general view on the state-of-the-art of the art of several topics on the covered fields. In particular, the book presents recent developments on discrete-time Markov control or decision processes under different contexts: discounted and average criterion as well as sample-path and constrained optimality; continuous-time controlled problems for diffusion processes, jump Markov processes, and semi-Markov processes; optimal stopping problems; global optimization; and the existence of solutions of stochastic partial differential equations. Additionally the book contains important applications to inventory control problems and financial systems. Chapters are presented in alphabetical order by first author.

We express our deep gratitude to all the people who have collaborated to make this special volume a success. Mainly, we thank all the authors for their excellent and important contributions, as well as all the reviewers for their time and effort. We would also like to thank the Centro de Investigación en Matemáticas (CIMAT) and the Departamento de Matemáticas, Universidad de Sonora.

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Resume of Professor Onésimo Hernández-Lerma

Present Position: Full Professor "3F" (top level), Department of Mathematics, CINVESTAV-IPN

- Member of the Mexican National Research System (SNI): Area I (Basic Sciences), Level 3 (top level).

Special Awards

- *Sciences and Arts National Award* by the Government of México (2001).
- Doctor *Honoris Causa* by the Universidad de Sonora (2003).
- *Lázaro Cárdenas Medal* (IPN) 2008.
- *Scopus Prize* (Elsevier) 2008.
- *Thomson Reuters Award* 2009.

Research interests: Optimal control of stochastic systems, Multiobjective control problems, Stochastic games, Infinite–dimensional linear programming, Markov processes.

Academic Background

- Mexican Air Force College, 1964.
- Escuela Superior de Física y Matemáticas (ESFM) of the Instituto Politécnico Nacional (IPN), Licenciado en Física y Matemáticas, 1970.
- Division of Applied Mathematics, Brown University, M.Sc., 1976.
- Division of Applied Mathematics, Brown University, Ph.D., 1978.

Employment

- Mexican Air Force, 1964–1968.
- Escuela Superior de Ingeniería Mecánica y Eléctrica (ESIME) of the IPN, 1968–1988.
- Universidad Autónoma Metropolitana, Azcapotzalco, 1974–1975.
- Centro de Investigación y de Estudios Avanzados, Mathematics Department, 1978—present. Chairman, 1992–1997, 2011–2015.

Visiting Appointments

- Universidad de los Andes (Mérida, Venezuela), 1971–1972.
- University of Texas at Austin, 1982–1983. One-month visits: 1984, 1985, 1986, 1987.
- LAAS-CNRS (Toulouse, France). Several one-month visits per year, during 1986–2001.
- Texas Tech University, 1987–1988.
- University of Padova (Padova, Italy). Two months, 1991.
- Universidad Carlos III de Madrid. Two months, 2000, 2002.

Visiting Postdoctoral Fellows

- Nadine Hilgert, INRA–ENSA.M, Montpellier, France, January–August 1999
- Xianping Guo, Zhongshan University, Guangzhou, P.R. China, August 2000–2002
- Tomás Prieto Rumeau, Universidad Complutense de Madrid, Spain, August 2003–January 2004

Former Ph.D. Students

Rolando Cavazos Cadena	CINVESTAV	1985
Roberto S. Acosta Abreu	CINVESTAV	1987
Sergio O. Esparza Núñez	Texas Tech Univ.	1989
Daniel Hernández Hernández	CINVESTAV	1993
Raúl Montes de Oca Machorro	UAM–Iztapalapa	1994
Fernando Luque Vásquez	FC–UNAM	1997
Oscar Vega Amaya	UAM–Iztapalapa	1998
Juan González Hernández	FC–UNAM	1998
César E. Villarreal Rodríguez	CINVESTAV	1998
J. Rigoberto Gabriel Argüelles	CINVESTAV	2000

Raquiel R. López Martínez	CINVESTAV	2001
Jorge Alvarez Mena	CINVESTAV	2002
Guadalupe Carrasco Licea	FC–UNAM	2003
Mario A. Villalobos Arias	CINVESTAV	2005
Héctor Jasso Fuentes	CINVESTAV	2007
Armando F. Mendoza Pérez	CINVESTAV	2008
Beatris A. Escobedo Trujillo	CINVESTAV	2011

Associate Editor Positions

- SIAM Journal on Control and Optimization (1991–1996)
- Boletín de la Sociedad Matemática Mexicana, 3a. serie (1995–2005)
- Journal of Mathematical Systems, Estimation, and Control (1992–1998)
- Applicationes Mathematicae (Warsaw) (1999–present)
- Top, journal of the Spanish Society of Statistics and Operations Research, SEIO (2001–2006)
- Information Technology for Economics and Management (ITEM) (2001–2005)
- Morfismos, journal of the CINVESTAV Mathematics Department (1997–present)
- Revista Mexicana de Economía y Finanzas (ReMEF) (2002-2007)
- International Journal on Stochastic Analysis (2010–present)
- Journal of Dynamics and Games (2011-)

List of Publications by Onésimo Hernández-Lerma

Books and Monographs

1. *Métodos de Fourier en la Física y la Ingeniería*, Editorial Trillas, México, 1974.
2. *Elementos de Probabilidad y Estadística*, Fondo de Cultura Económica, México, 1979; 2nd. printing, 1982.
3. *Adaptive Markov Control Processes*. Springer–Verlag, New York, 1989.
4. *Annals of Operations Research* Special Volumes **28** and **29** (1991) on Markov Decision Processes, with J.B. Lasserre, Guest Editors.
5. *Lectures on Continuous–Time Markov Control Processes*. Aportaciones Matemáticas, Advanced Texts series Vol. 3, Sociedad Matemática Mexicana, 1994.
6. *Discrete–Time Markov Control Processes: Basic Optimality Criteria*. Springer–Verlag, New York, 1996, with J.B. Lasserre.
7. *Further Topics on Discrete–Time Markov Control Processes*. Springer–Verlag, New York, 1999, with J.B. Lasserre.
8. *Markov Chains and Invariant Probabilities*. Birkhäuser, Basel, 2003, with J.B. Lasserre.
9. *Elementos de Probabilidad y Estadística*, Sociedad Matemática Mexicana, 2003, with A. Hernández del Valle.
10. *Continuous–Time Markov Decision Processes: Theory and Applications*. Springer–Verlag, 2009, with X.P. Guo.
11. *Selected Topics on Continuous–Time Controlled Markov Chains and Markov Games*. Imperial College Press, 2012, with T. Prieto–Rumeau.

Papers

1. *Series de Fourier: Breve introducción histórica*, Miscelánea Matemática No. 7, 1974, pp. 13–24.
2. *Probabilidad y estadística en el nivel primario*, Matemáticas y Enseñanza No. 2, 1975, pp. 23–42, with L.G. Gorostiza.
3. *Lyapunov criteria for stability of differential equations with Markov parameters*, Bol. Soc. Mat. Mexicana **24** (1979) pp. 27–48.

4. *Exit probabilities for a class of perturbed degenerate systems*, SIAM J. Control Optim. **19** (1981), pp. 39–51.
5. *Control óptimo de procesos de difusión markovianos*, Ciencia (journal of the Mexican Academy of Sciences) **32** (1981), pp. 39–55, with W.H. Fleming.
6. *Modelos matemáticos en amibiasis*, Sigma **7** (1981), pp. 131–138, with R. Cano Mancera and R. López–Revilla.
7. *Modelos matemáticos de adhesión celular con aplicaciones a la adhesión de trofozoítos de Entamoeba histolytica*, Ciencia (journal of the Mexican Academy of Sciences) **33** (1982), pp. 107–117, with R. Cano Mancera and R. López Revilla.
8. *Adaptive control of service in queueing systems*, Syst. Control Lett. **3** (1983), pp. 283–289, with S.I. Marcus.
9. *Identification and approximation of queueing systems*, IEEE Trans. Automatic Control **AC–29** (1984), pp. 472–474, with S.I. Marcus.
10. *Modelos matemáticos de la adhesión de trofozoítos de Entamoeba histolytica a eritrocitos humanos*, Acta Mexicana de Ciencia y Tecnología **II** (1984), No. 5, pp. 65–75, with R. Cano Mancera and R. López–Revilla.
11. *Control adaptable iterativo de sistemas markovianos con costo promedio*, Acta Mexicana de Ciencia y Tecnología **II**, No. 6 (1984), pp. 63–68, with R.S. Acota–Abreu.
12. *Modelado, estimación y control de recursos pesqueros, I. Modelos de poblaciones*, Acta Mexicana de Ciencia y Tecnología, **II** No. 7 (1984), pp. 51–61.
13. *Optimal adaptive control of priority assignment in queueing systems*, Syst. Control Lett. **4** (1984) 65–72, with S.I. Marcus.
14. *Adaptive control of discounted Markov decision chains*, J. Optim. Theory Appl. **46** (1985), pp. 227–235, with S.I. Marcus.
15. *Nonstationary value–iteration and adaptive control of discounted semi–Markov processes*, J. Math. Anal. Appl. **112** (1985), pp. 435–445.
16. *Approximation and adaptive policies in discounted dynamic programming*, Bol. Soc. Mat. Mexicana **30** (1985), pp. 25–35.
17. *Iterative adaptive control of denumerable state average–cost Markov systems*, Control & Cybernetics **14**, No. 4 (1985), pp. 313–322, with R.S. Acosta Abreu.
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38. *Recurrence conditions for Markov decision processes with Borel state space: A survey*, Ann. Oper. Res. **28** (1991), 29–46, with R. Montes de Oca and R. Cavazos–Cadena.

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42. *Equivalence of Lyapunov stability criteria in a class of Markov decision processes*, Appl. Math. Optim. **26** (1992), 113–137, with R. Cavazos–Cadena.
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46. *Monotone approximations for convex stochastic control problems*, J. Math. Syst., Estimation, and Control **4** (1994), 99–140, with W. Runggaldier.
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48. *Weak conditions for average optimality in Markov control processes*, Syst. Control Lett. **22** (1994), 287–291, with J.B. Lasserre.
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52. *Average cost Markov control processes with weighted norms: existence of canonical policies*. Appl. Math. (Warsaw) **23** (1995), 199–218, with E. Gordienko.
53. *Linear programming and infinite horizon problems of deterministic control theory*. Bol. Soc. Mat. Mex. (3rd series) **1** (1995), 59–72, with D. Hernández–Hernández.
54. *Numerical aspects of monotone approximations in convex stochastic control problems*. Ann. Oper. Res. **56** (1995), 135–156, with C. Piovesan and W.J. Runggaldier.
55. *Conditions for average optimality in Markov control processes with unbounded costs and controls*, J. Math. Syst., Estimation, and Control **5** (1995), 459–477, with R. Montes de Oca.
56. *A counterexample on the semicontinuity of minima*. Proc. Amer. Math. Soc. **123** (1995), 3175–3176, with F. Luque Vásquez.

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58. *Value iteration in average cost Markov control process on Borel spaces*. Acta Appl. Math. **42** (1996), 203–222, with R. Montes–de–Oca.
59. *Average optimality in Markov control processes via discounted cost problems and linear programming*. SIAM J. Control Optim. **34** (1996), 295–310, with J.B. Lasserre.
60. *Existence of bounded invariant probability densities for Markov chains*. Statist. Prob. Lett. **28** (1996), 359–366, with J.B. Lasserre.
61. *The linear programming approach to deterministic optimal control problems*. Appl. Math. (Warsaw) **24** (1996), 17–33, with D. Hernández–Hernández and M. Taksar.
62. *An extension of the Vitali–Hahn–Saks Theorem*. Proc. Amer. Math. Soc. **124** (1996), 3673–3676; correction, ibid. **126** (1998), p. 949, with J.B. Lasserre.
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64. *Policy iteration for average cost Markov control processes on Borel spaces*. Acta Appl. Math. **47** (1997), 125–154, with J.B. Lasserre.
65. *Cone–constrained linear equations in Banach spaces*. J. Convex Anal. **4** (1997), 149–164, with J.B. Lasserre.
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