

# **Curriculum Vitæ**

**Felisa J. Vázquez-Abad**

March 9, 2004

## Personal Data

<b>Name</b>	<b>Felisa J. Vázquez-Abad</b>
<b>Position</b>	Associate Professor (Professeur agrégé), Department of Computer Science and Operations Research (Département d'informatique et recherche opérationnelle), University of Montreal
<b>Address</b>	Département d'informatique et recherche opérationnelle C.P. 6128 Succursale Centre-Ville, Montréal, Québec H3C 3J7. CANADA
<b>Telephone</b>	(514) 343-6952, FAX: (514) 343-5834
<b>Web Site</b>	<a href="http://www.iro.umontreal.ca/~vazquez">http://www.iro.umontreal.ca/~vazquez</a>
<b>Citizenship</b>	Canadian
<b>Languages</b>	Spanish, English, French.

## Degrees

Degree	University	Country	Year
Ph.D. in Applied Mathematics	Brown University	U.S.A.	1989
M.Sc. in Statistics and Operations Research (thesis with honors)	Universidad Nacional Autónoma de México (UNAM)	Mexico	1984
B.Sc. in Physics	UNAM	Mexico	1983

## Theses:

- *Stochastic recursive algorithms for optimal routing in queueing networks* . Ph.D. Thesis. Division of Applied Mathematics, Brown University, May 1989.  
**Advisor:** Harold J. Kushner.
- *Simulación probabilística para la toma de decisiones, con aplicaciones en el sector energético.* (Stochastic simulation for decision making, with applications in the energy sector.) Tesis de Maestría. Colegio de Ciencias y Humanidades, Instituto de Investigación en Matemáticas Aplicadas y Sistemas, UNAM, México, diciembre 1984.  
**Advisor:** Diego Bricio Hernández.
- *Evolución temporal del decaimiento en la mecánica cuántica* . (Time evolution of nuclear decay in quantum mechanics.) Tesis de licenciatura. Facultad de Ciencias, UNAM, México, abril 1983.  
**Advisor:** Gastón García-Calderón.

## Professional Activities

### Position Description

- **06/93-present** *Professor, Univ. de Montréal.* Adaptive control of stochastic discrete event process, sensitivity analysis, simulation, theory and applications of automatic learning for optimization, queueing networks, weak convergence theory, probability theory, Markov decision processes.
- **10/01-06/02** *Principal Research Fellow, Melbourne University.* Stochastic approximation and gradient estimation for general Markov chains, with applications in detection and control problems. Collaboration with V. Krishnamurthy, Department of Electrical and Electronic Engineering.
- **08/99-12/99** *Research Fellow, Melbourne University.* Stochastic approximation for telecommunications problems. Collaboration with V. Krishnamurthy, Department of Electrical and Electronic Engineering.
- **10/98-08/99** *Research Fellow, Melbourne University.* Simulation for performance evaluation and control of all-optical networks using time division multiplexing for wavelength sharing of multiple callers, Department of Electrical and Electronic Engineering.
- **03/93 - 06/93** *Visiting Researcher, Univ. de Montréal.* Sensibility analysis for optimal on-line routing in queueing networks.
- **12/91 - 12/92** *Research Associate, INRS-Télécom.* Applications and convergence study of learning automata algorithms for optimal decentralized flow control of high speed, packet-switched telecommunication networks. Canadian Institute for Telecommunications Research (CITR), Networks of Centers of Excellence program of the Canadian Government.
- **06/90 - 11/91** *Postdoctoral Student, INRS-Télécom.* Collaboration with Lorne G. Mason in the CITR project of decentralization of flow control for high speed ATM networks.
- **07/89 - 05/90** *Visiting Assistant Professor, Brown Univ.* Collaboration with Harold J. Kushner in a systematic study of numerical methods for solving stochastic differential equations under control.
- **06/89 - 07/89** *Visiting Research Associate, Brown Univ.* Collaboration with Harold J. Kushner in a systematic study of numerical methods for solving stochastic differential equations under control.
- **07/86 - 06/87** *Research Assistant, Brown Univ.* Collaboration with David Gottlieb in the preparation of the lecture notes on numerical solutions of PDE's.
- **04/83 - 01/85** *Research Assistant, UNAM.* Development of operation research models and application of integer programming for optimal resource allocation in the Energy sector.

## Academic Distinctions

### Awards and Prizes

- **2000 Jacob Wolfowitz Prize** for Theoretical Advances in the Mathematical and Management Sciences, for the paper:

P. L'Ecuyer, B. Martin and F.J. Vázquez-Abad (1999) "Functional Estimation for a Multicomponent Age Replacement Model", *American Journal of Mathematical and Management Sciences*, vol 19, Nos. 1 & 2: 135–156.

- **Award** Facultad de Ciencias (UNAM) given to the three top students of my class for the B.Sc. in Physics, 1984.

### Distinction, Institution

Distinction, Institution	Period
Young Researcher Award, FCAR <sup>1</sup>	06/94-06/97
Women in Faculty Award, NSERC <sup>2</sup>	06/93-06/98
NASA Fellowship	09/87-05/88
Elected Member of the Sigma-Xi Scientific Society, AMS	1987
Elected Associate Member of the Sigma-Xi Scientific Society, AMS	1986
Tuition scholarship, Brown University	01/87-05/89
Stipend Scholarship, IIMAS <sup>3</sup> , UNAM	01/85-05/88
Scholarship, IIMAS, UNAM	10/82-03/83
Scholarship, IFUNAM <sup>4</sup> , UNAM	10/79-10/80

<sup>1</sup> Canadian Funds for the Advancement of Research.

<sup>2</sup> Natural Sciences and Engineering Research Council of Canada.

<sup>3</sup> Research Institute in Applied Mathematics and Systems, UNAM.

<sup>4</sup> Physics Institute, UNAM.

## Honorary Positions and International Collaborations

- **NSERC** (*Natural Sciences and Engineering Research Council of Canada*) Selection Committee, University Faculty Awards, since 2001.
- **Visiting Scholar**, École Nationale de Ponts et Chaussées, Champs sur Marne, France, August 2002.
- **Invited Professor** at the Departamento de Ingeniería en Sistemas y Automática, Universidad de Valladolid, Spain: doctoral course, June-August 2002. Industry collaboration with the Centre for Sugar Technology to implement MPC in real time for the production of sugar.
- **Visiting Scholar** at the Stochastic Networks Group, EURANDOM, Eindhoven, August 2000.
- **Principal Investigator, Associate Professor**, Department of Electrical and Electronic Engineering, Melbourne University, June 2000 - June 2003.
- **Visiting Professor**, INRS-Telecommunications, Université du Québec, March 1998 - June 2003.
- **Visiting Researcher**, Department of Mathematics and Statistics, Melbourne University, December 1997 to July 1999.

## Invited Lectures

- (with Baltcheva) “Intelligent Simulation for the Estimation of the Uplink Outage Probabilities in CDMA Networks”, Summer Research Institute, École Polytechnique Fédérale de Lausanne, July 2001. **Host:** Pierre Brémaud. <http://ic.epfl.ch/page20807.html>.
- “Towards Adaptive Public Transportation: Local Sensitivity Analysis”, TUDelft August 26 2002. **Host:** Bart de Schutter.
- “Efficient simulation for web applications”, TU Eindhoven July 15 2001. **Host:** Onno Boxma.
- “A self-optimised Importance Sampling scheme for simulation”, Ecole Normale Supérieure, Paris, July 10, 2001. **Host:** François Baccelli.
- “Adaptive Algorithms for Fairness in Telecommunications Networks”, Summer Research Institute, École Polytechnique Fédérale de Lausanne, July 2001. **Host:** Jean-Yves Le Boudec. <http://ic.epfl.ch/page20807.html>.
- “Efficient simulation for assessing the loss probability in telecommunication networks”, Corporate Research Centre ALCATEL, Madrid, Spain, September 5, 2000. **Host:** Manuel Poza Jiménez.
- “Gradient Estimation for Discrete Event Systems Performance Measures: an overview”, EURANDOM, Eindhoven, the Netherlands, August 2000. **Host:** Onno Boxma.
- “Workshop on Weak Convergence of Stochastic Approximations and Applications to Telecommunication Networks”, Dept of Electrical and Electronic Engineering, Melbourne University, Oct-Nov 1999. **Host:** Vikram Krishnamurthy.
- “On the Consistency of the Phantom RPA Estimators”, TU Delft, The Netherlands, July 21, 1999. **Host:** Bernd Heidergott.
- “Using Simulation Wisely: a Close Look at Rare Event Estimation”, The United Technologies Sponsored Seminar Series in Manufacturing and Systems Engineering, Boston University, April 2nd, 1999. **Host:** Christos G. Cassandras.
- “Accelerated Simulation via Self-Optimized Importance Sampling”, Brown University, Providence RI, December 2, 1998. **Host:** Harold J. Kushner.
- “Self-Optimising Mechanisms for DES”, Department of Systems Engineering, Australian National University, Canberra September 2, 1997. **Host:** John Moore.
- “Phantom RPA Method for Estimating Sensitivities, with and Application to Risk Theory”, Department of Mathematics and Statistics, University of Melbourne, August 14 and 28, 1997. **Host:** Tim Brown.
- “On the Adaptive Control of Teletraffic Broadband Networks Using Decentralized Stochastic Approximation”, Software Engineering Research Centre, RMIT and The University of Melbourne, August 6th, 1997. **Host:** Darryl Veitch.
- “Algorithmic Analysis of Simulation Methods via Branching Processes”, presented at the IV Symposium in Probability and Stochastic Processes, Guanajuato, April 1996. **Host:** Luis G. Gorostiza.
- “Convergence Analysis for Stochastic Optimization Methods”, Institute for Systems Research, University of Maryland, College Park, December 12, 1994. **Host:** Michael Fu.
- “On the convergence of adaptive control algorithms”, University of Massachusetts in Amherst, Amherst, July 14, 1994. **Host:** Christos G. Cassandras.

## Service to the Community

### Service to the Department

Besides my active participation in international forums and associations to foster interest of my research group, I have been a member of various committees in the Department of Computer Science and Operations Research at the University of Montreal. In particular I have undertaken the following responsibilities:

- Undergraduate and Graduate student counselor,
- member of the Graduate admissions committee,
- member of the hiring committee,
- member of the teaching evaluation committee, and
- representative of the Department for the Masters programme in Mathematical and Computational Finance,

In October 2002 I volunteered to represent my Department in the 2002 Innovation Forum of the *adriq* (association de la recherche industrielle du Québec).

Since 2001 I am a member of the Selection Committee for the University Faculty Awards (NSERC), a Canadian Government programme to help minorities (women, aboriginal peoples, etc) to establish University careers. During my visit to Melbourne University I was also a member of the Diversity Committee of the Faculty of Engineering in Melbourne University.

### Editorial and Diffusion

- *Associate Editor*, Simulation Area, *Operations Research Letters*, since 2003.
- *Associate Editor*, Simulation Area, *Management Science*, since 2001.
- *Web Editor*, INFORMS College of Simulation, since July 1998.
- *Associate Editor*, Conference Editorial Board of the IEEE Control Systems Society, since 1998.
- Member of the Scientific Committee, *WODES*, Reims, France, Sept 2004.
- Member of the Scientific Committee, *WODES*, Zaragoza, Spain, Sept 2002.
- Member of the Scientific Committee, *WODES*, Ghent, Belgique, May 2000.
- Invited member of the European Simulation Society *EUROSIS*, since 2003.

## Associations

- Member (international) of the European Network of Excellence MOSAIC, since 2003.
- Member, *groupe d'études et de recherche en analyse de décisions* (GERAD), University of Montreal, since 2000.
- *IEEE* Communications Society, Member since 1999.
- *IEEE* Control Society, Member since 1998.
- INFORMS (formerly Operations Research Society of America ), Member since 1993.
- Society for Industrial and Applied Mathematics (SIAM), Member 1994-1999.
- American Mathematical Society (AMS), Member 1986 - 1992.

## Reviewer

Regular referee for *QUESTA*, *J DEDS*, *Mngmnt Sci*, and *IEEE Trans Autom Control*, (since 1992), for the *IEEE Conference on Decision and Control* (since 1994), for *Operations Research*, *Advances in Applied Probability*, *INFOR* and *Computers and Operations Research* (since 1995), for the *Equilibrium Colloquium* organized by the Center for Transportation (Univ of Montreal, 1997), for *The Journal of the Operational Research Society* and *IEEE Trans on Communications* (since 1999), for *Transportation Science* and *SIAM J on Optim*, *ACM Transactions on Modeling and Computer Simulation (TOMACS)* (since 2000), *Telecommunication Systems* (since 2001).

## Other

I had the opportunity to help Irina Baltcheva and Katerine Martin, who were then Undergraduate students in Montreal, to visit the ARC Special Research Centre for Ultra-Broadband Information Networks (CUBIN) at the Department of Electrical and Electronic Engineering, Melbourne University, as *occupational trainees* from January to March 2002. I was spending a leave of absence there to conduct research and they helped develop the algorithms and computer code. This was a very enriching experience for them and their work was of the highest quality. In July-August 2002, I obtained an invitation for Irina to visit the Department of Systems Engineering and Automatic Control at the University of Valladolid, where I was teaching a Doctoral course. She was interested by the research in their lab and she is currently involved in the project to optimise the production of sugar from beetroot, at the CTA (center for sugar technology).

From this experience, I proposed to University College in Melbourne to create an International Programme to help Undergraduate students conduct research overseas. I will help organise the programme in order for academic visitors to the College around the world to be able to offer summer research jobs to Undergraduates. I believe that the exchange not only broadens the student's personal experience but also helps them understand the dynamics of collaborations within different cultures and languages. I plan to continue to encourage these interchanges to help students become involved with research, both at universities as well as industrial projects. Several students in Montreal have already expressed interest in working with me, because they are attracted to the possibility of undertaking summer research projects abroad.

## Research Grants

Organisation	Project and collaborators	Amount Asked (per year)	Granted (per year)	Period
NSERC Strategic	Synthesis of agile photonic networks with stochastic demands with B. Sansò and A. Girard	\$ 150,000	\$150,000	2002-2005
FCAR Teams	Simulation of Stochastic Models, with P. L'Ecuyer (renewal)	\$69,000	\$ 56,000	2003-2005
MEU Melbourne Univ	BestNet: An Interactive Learning Tool for Network Design, with M. Zukerman	\$10,000	\$11,000	2000
NSERC Individual	Simulation and Optimisation of Complex Stochastic Discrete Event Systems (DES)	\$58,000	\$24,450	2000-2004
FCAR Teams	Simulation of Stochastic Models, with P. L'Ecuyer Equipment	\$60,000 \$10,000	\$31,000 \$10,000	1999-2002
NSERC Equipment	Upgrade of Optimisation Laboratory, with P. L'Écuyer, J. Ferland, J.Y. Potvin P. Marcotte, et M.Gendreau, U. de M.	\$59,591	\$35,474	1999
MEU Melbourne Univ	A Simulation Based Network Design Learning Tool, with M. Zukerman	\$50,000	\$40,000	1999
NSERC	Automated Machine Learning for Adaptive Control of Stochastic DES Individual Research Grant	\$45,000	\$21,000	1996-2000
FCAR Teams	Probabilistic Methods in Computer Science P. L'Ecuyer, Gilles Brassard, J. Ferland.	\$95,000	\$44,000	1995-98
NSERC Equipment	UNIX Server for the Optimisation Lab. Group with J. Ferland, P. L'Écuyer, P. Marcotte, et P. Michelon, U. de M.	\$86,280	\$86,280	1994
FCAR 95-NC-1375	Automatic Learning Mechanisms for Discrete Event Stochastic Systems under Control Equipment	\$15,000 \$17,000	\$13,700 \$17,000	1994-97 1994
CAFIR Démarrage	Sensitivity Analysis for Discrete Event Stochastic Systems	\$7,500	\$5,000	1993
NSERC WFA 0139015	Sensitivity analysis for Optimization of stochastic DEDS. Salary Contribution	\$26,500 \$16,500 –	\$20,000 \$20,000 \$30,500	1993-94 1994-96 1993-98



## Teaching

The first courses mentioned below are invited tutorials for which I developed all the course material and syllabus. The rest of the courses are included in the regular university curriculum. At the University of Montreal, regular courses are 13 weeks, 5 hours per week of student contact. The level “certificat” is a Professional Diploma between BSc and MSc, mostly for adult, continuing education students. Professors are responsible for structuring the material, and for the pedagogical design of the course development and evaluations. Related course material is available from my web site:

<http://www/iro.umontreal.ca/~vazquez>.

Course	Description
<i>Theoretical Foundations of Simulation</i>	Postdoctoral, 15 hours course Valladolid, Spain (2002)
<i>Sensitivity Analysis for Discrete Event Systems</i>	Postdoctoral, 6 week course, Ghent, Belgium (2000).
<i>Stochastic Approximation, with applications to fairness in telecommunications</i>	Summer Research Institute, Lausanne, Switzerland (2001).
<i>Weak Convergence of Stochastic Approximations</i>	Postdoctoral, 9 week course, University of Melbourne (1999).
<i>Statistical Principles of Simulation</i>	Graduate, Univ of Montreal (1997-2002).
<i>Non-linear optimisation Simulation</i>	B Sc, Univ of Montreal (2001,2003).
<i>Stochastic Models</i>	B Sc, Univ of Montreal (2000).
<i>Introduction to Operations Research</i>	B Sc, Univ of Montreal (1993-2000).
<i>Non-linear optimisation</i>	B Sc, Univ of Montreal (1993, 2002).
<i>Operations Research Models</i>	Certificat, Univ of Montreal (1993).
<i>Quantum Mechanics</i>	Certificat, Univ of Montreal (1992-94 & 2000).
<i>Classical Mechanics</i>	B Sc Physics Dept, UNAM (1982-1983).
	B Sc Physics Dept, UNAM (1982-1983).

### Web Site Development

- **Stochastic Model Quizzes:** As part of the course on Stochastic Modeling, I prepared a series of pages with quizzes on stochastic models that can be used to practice, as well as a basis for exam questions. All the scripts are made with simple javascript.
- **SimSpiders:** An on-going effort co-authored by Yanick Champoux to create a tutorial on stochastic simulation. Most of the site contains useful information for the practitioner and students. Some of the pages show the concepts via interactive simulations. Our simulations are programmed in java, and all cgi's are C programs. We expect to be able to use the tool as an aid for teaching such courses and continue developing the site as a useful source of information for the practitioners.
- **BestNet:** In collaboration with Moshe Zukerman (University of Melbourne), we proposed the concept of a web site for training and teaching network design, that complements the traditional course material. From the main ideas we are now expanding the concept of the site, focusing on the training of teachers to promote utilization of hypermedia and help them incorporate web-based simulations into their courses.

## Participation in Training

### Theses supervision

Expected dates are in parenthesis.

Date	Name	Title of Thesis	Degree	Direction
On-going (2004)	Arnoldo Rodríguez	Tele-learning Website model with interactive simulations design.	Ph.D. IRO	Vázquez-Abad and Aïmeur
On-going (2004)	Kim Lévy	Optimal tarification for the airline yield management problem	M.Sc. IRO	Vázquez-Abad and Marcotte
On-going (2004)	Katerine Martin	MDP formulation and on-line control for optical burst switched networks	M.Sc. IRO	Vázquez-Abad and Krishnamurthy
On-going (2003)	Irina Baltcheva	Scalable Flow control for OBS telecommunication networks	M.Sc. IRO	Vázquez-Abad
On-going (2003)	Eloïm Gutiérrez	OBS architecture and performance evaluation	M.Sc. IRO	Vázquez-Abad Sansò and L'Ecuyer
2000	Noriega, Yolanda	Optimisation de fréquences dans un réseau de transport	M.Sc. IRO	Vázquez-Abad and Florian
1999	Kamté, Bernard	Simulation of a self-optimising network: the case of IP over ATM	M.Sc. INRS	Mason and Vázquez-Abad
1998	Le Quoc, Phong	Estimation de la probabilité de ruine et ses dérivées par simulation	M.Sc. IRO	Vázquez-Abad
1996	Martin, Benoit	Estimation fonctionnelle dans le cadre de politiques de remplacement dans un système à plusieurs composantes	M.Sc. IRO	L'Ecuyer and Vázquez-Abad

### Assistantships and Project Supervision

- **07-12/2002:** *Simon Hardy*. Comparison between simulated annealing and stochastic comparisons methods for estimating molecular binding. Course project 2002.
- **09/02-today:** *Christian Dorion*. Stochastic approximation to learn the optimal parameters of a neural network for optimal portfolio selection. Course project 2002.
- **07-12/2002:** *Irina Baltcheva and Claudine Nadeau*. Improved Model Based Predictive Control for industrial chemical plants, using advanced simulation techniques for non linear optimisation in real time. Invited summer project (Baltcheva), at the *Centro de Tecnología Azucarera*, Valladolid, Spain. Continued (Nadeau) as course project 2002.
- **01/02-03/02:** *Irina Baltcheva and Katerine Martin*. Summer project at the Department of Electrical and Electronic Engineering, University of Melbourne, as *occupational trainees* working on self-optimised controllers for Markov Decision Processes with applications to telecommunication and military defense problems, [32].
- **07-12/01:** *Francis Forget et Dominique Tourillon*. Development of simulator in SSC language for a subway network. This work helped develop the computer code used in several publications [30, ?].

- **06/00-08/01 and 2001:** *Irina Baltcheva*. Importance Sampling for Estimation of Outage Probability in Mobile Cellular Networks, Summer project, continued to course project 2001, [34, 65].
- **06/00-08/00 and 2001:** *Katerine Martin*. Call *versus* Cell arrival sensitivities in a Dynamic Polling ATM Switch, Summer project, continued to course project 2001:  
<http://www.iro.umontreal.ca/~martink/etude/projet/>.
- **06/00-08/00:** *Maryse Boisvert*. Implementation of the Network Design Site, BestNet, Summer project.
- **01/00-08/00:** *Fabrice Plançon*. Simulation of a Subway network for Adaptive Frequency Allocation, course project 2000, co-supervised by L. Zubieta. This project helped develop the computer code that we used for several publications [37, ?].
- **06/99-09/99:** *Jelena Kapor*. Simulation of surrogate estimators for a subway station with transfers, Bishops University, co-direction with L. Zubieta [32, ?].
- **09/98-03/99:** *Kampté, Bernard*. Estimating performance of IP over ATM using isarithmic window flow control, MSc Thesis.
- **09/96-06/98:** *Cepeda Jüneman, Manuel*. Simulation of a manufacturing plant with adaptive routing, M Sc. project. Also, study of optimal threshold for inventory models [41], course project 1998.
- **09/96-06/98:** *Phong, Le Quoc*. Estimating derivatives of ruin probabilities, M.Sc Thesis, citejors.  
**09/96-12/98:** *Yolanda Noriega Zárate*. Optimal frequency adjustment of subway trains, M.Sc. Thesis.
- **06/07-09/97:** *Julie Roy*. Preparing the codes for estimating sensitivities in an ATM switch, w.r.t. call and cell arrival rates.
- **06/97-08/97:** *Ianis Queval*. Simulation of the swapping and disappearing phantom methods, citejors. Implementation of the Harmonic Gradient phantom estimators, [51, 5].
- **06/97-07/97:** *Marc Saettano*. Simulation of the swapping and disappearing phantom methods, [51, 5].
- **09/93-09/96:** *Kim Davis*. Development and simulation of decentralized adaptive control mechanisms. Programming and testing several sensitivity analysis methods.
- **08/95-04/96:** *Ran Ezerzer*. Coding the program for the optimal production rates in a FMS.
- **06/94-03/95:** *Patrice Dion*. Analysis of performance of simulators with Object Oriented architecture. Preparation of various simulations to test sensitivity analysis methods.
- **06/93-09/93:** *Sophie Villeneuve*. Adaptation of simulation programs to the UNIX and DOS platforms.

## Publications

My contribution is primarily theoretical, but I am also interested in applications of stochastic optimisation and simulation, as well as the study of the computational aspects of the algorithms. I have published with internationally renowned researchers, such as Pierre Brémaud, Christos Cassandras, Pierre L'Ecuyer, Harold Kushner and Sid Yakowitz. Although I enjoy formulating innovative methodologies, I have made a conscious effort to apply the methods for automatic learning to practical problems. These papers are primarily co-authored with my students.

### Book and Book Chapters

- [1] A. Girard, B. Sansò and F.J. Vázquez-Abad (2004) *Performance Evaluation and Planning Methods for the Next Generation Internet*, in preparation.
- [2] F.J. Vázquez-Abad (2000) "A Course on Sensitivity Analysis for Gradient Estimation of DES Performance Measures", Part I of III, in *Discrete Event Systems, Analysis and Control*, R. Boel and G. Stremersch Editors, Kluwer Academic Publishers, Boston: 3–28.

### Refereed Journal Papers

- [3] F.J. Vázquez-Abad, J. White, L.H. Andrew and R. Tucker (2004) "Does header length affect performance in optical burst switched networks?", *Journal of Optical Networking*, **3** : ??-??.  
<http://www.osa-jon.org/>
- [4] F.J. Vázquez-Abad, L. Andrew and D. Everitt (2002) "Estimation of Blocking Probabilities in Cellular Networks with Dynamic Channel Assignment", *ACM-Trans on Modeling and Computer Simulation*, **vol 12**, No. 1, Special Issue on Rare Event Estimation.
- [5] F.J. Vázquez-Abad and S.H. Jacobson (2001) "Phantom Harmonic Gradient Estimators for Nonpreemptive Priority Queueing Systems", *INFORMS Journal on Computing*, **vol 13**, No 3: 1-15.
- [6] F.J. Vázquez-Abad and P. LeQuoc (2001) "Sensitivity Analysis for Ruin Probabilities", *Journal of the Operational Research Society*, **vol 52**, No 1: 71-81.
- [7] S. Yakowitz, P. L'Ecuyer, and F.J. Vázquez-Abad (2000) "Global Stochastic Optimization with Low-Dispersion Point Sets", *Operations Research*, **vol 48**, No 6 : 939-950.
- [8] F.J. Vázquez-Abad (2000) "RPA Pathwise Derivative Estimation of Ruin Probabilities", *Insurance Mathematics and Economics*, No. 26: 269–288.
- [9] P. L'Ecuyer, B. Martin and F.J. Vázquez-Abad (1999) "Functional Estimation for a Multicomponent Age Replacement Model", *American Journal of Mathematical and Management Sciences*, vol 19, Nos. 1 & 2, Special issue on Modern Digital Methodology: 135–156.
- [10] Vázquez-Abad, F., Mason, L.G. (1999) "Decentralized adaptive isarithmic flow control for high speed data networks", *Operations Research*, **vol 47**, No 6: 928-942.
- [11] F.J. Vázquez-Abad (1999) "Strong Points of Weak Convergence: A Study Using RPA Gradient Estimation for Automatic Learning", *Automatica*, **vol 35**, No 7: 1255–1274.

- [12] Vázquez-Abad, F.J., Cassandras, C.G., Julka, V. (1998) “Centralized and Decentralized Asynchronous Optimization of Stochastic Discrete Event Systems”, *IEEE Trans on Automatic Control*, **vol 43**, No. 5: 631-655.
- [13] L’Ecuyer, P., Vázquez-Abad, F.J. (1997) “Functional Estimation with Respect to a Threshold Parameter”, *DEDS, Theory and Appl.*, **vol 7**, No. 1: 69-92.
- [14] Vázquez-Abad, F.J., Mason, L.G. (1996) “Adaptive control of DEDS under non-uniqueness of the optimal control”, *DEDS, Theory and Applications*, **vol 6**, No. 4: 323-359.
- [15] Kushner, H.J., Vázquez-Abad, F. (1996) “Stochastic approximations for systems of interest over an infinite time interval”, *SIAM J. on Control and Optim.*, **vol 34**, No. 2 : 712-756.
- [16] Brémaud, P., Vázquez-Abad, F. (1992) “On the pathwise computation of derivatives with respect to the rate of a point process: the phantom RPA method”, *Queueing Systems, Theory and Appl.*, 10: 249 - 270.
- [17] Vázquez-Abad, F., Kushner, H.J. (1992) “Estimation of the derivative of a stationary measure with respect to a control parameter”, *Journal of Appl. Prob.*, 29: 343 - 352.

### Submitted

- [18] B. Heidergott, G. Pflug and F.J. Vázquez-Abad, “Measure-Valued Differentiation for Stochastic Systems: From Simple Distributions to Markov Chains”, to be submitted to *Operations Research*.
- [19] F.J. Vázquez-Abad and L. Zubieta, “Ghost simulation model for the optimisation of an urban subway system”, submitted to *DEDS Journal*.
- [20] L.H. Andrew and F.J. Vázquez-Abad, “Filtered and Pairwise Gibbs Samplers for Teletraffic Analysis”, submitted to *Performance Evaluation*.
- [21] F.J. Vázquez-Abad and B. Heidergott, “Sensitivity analysis for a class of service systems with bulk arrivals: a problem in public transportation”, under second revision, *IEEE Trans on Autom Control*.
- [22] F.J. Vázquez-Abad and V. Krishnamurthy, “Self Learning Control of Constrained Markov Decision Processes – A Gradient Approach”, under second revision, *IEEE Trans on Autom Control*.

### Refereed conferences with proceedings

- [23] K. Martin and F.J. Vázquez-Abad, “Efficient Concurrent Gradient Estimation for Network Optimization via Ersatz Estimators”, *Proceedings of the 43<sup>rd</sup> IEEE Conference on Decision and Control*, December 2004, submitted.
- [24] A. Rodríguez, Esmá Aïmeur and F.J. Vázquez-Abad, “E-Learning for complex Decision-Making with the support of a Web-based Adaptive ITS”, to appear in *Proceedings of the International Conference on Knowledge Engineering and Decision Support*, Porto, July 2004.
- [25] F.J. Vázquez-Abad and V. Krishnamurthy, “Constrained Stochastic Approximation Algorithms for Adaptive Control of Constrained Markov Decision Processes”, *Proceedings of the 42<sup>nd</sup> IEEE Conference on Decision and Control*, December 2003 : 2823–2828.

- [26] V. Krishnamurthy, K. Martin and F.J. Vázquez-Abad, “Implementation of Gradient Estimation to a Constrained Markov Decision Problem”, invited paper, *Proceedings of the 42<sup>nd</sup> IEEE Conference on Decision and Control*, December 2003 : 4841–4846.
- [27] F.J. Vázquez-Abad, A. Rodríguez and E. Aimëur, “Training the Teacher: A New Approach for Authoring ITSs for Teaching Decision-Making”, *Proceedings of the International Conference on Open and Online Learning (ICOOL)*, University of Mauritius, December 2003 : ??–??.
- [28] A. Rodríguez, E. Aimëur and F.J. Vázquez-Abad, “Combining Multi-criteria topics and resources for teaching complex decision-making skills”, *Proceedings of the II International Conference on Multimedia and IC Technologies*, Méndez-Vilas, Mesa González and Mesa González, Eds. Junta de Extremadura, Publisher, Badajoz, Spain, 2003 : ???–???
- [29] S. Dey and F.J. Vázquez-Abad. “Smart quantizers for recursive parameter estimation of hidden Markov models”, *Proceedings of the 6-th Baiona Workshop on Signal Processing in Communications*, Sept 2003 : 241-245.
- [30] F.J. Vázquez-Abad and L. Zubieta, “Simplifying Sensitivity Analysis in Subway Control”, *Proceedings of the 1<sup>st</sup> Industrial Simulation Conference (ISC’2003)*, Valencia, Spain, EUROSIS Editors: 423–428.
- [31] I. Baltcheva, S. Cristea, F.J. Vázquez-Abad and C. De Prada, “Simultaneous Perturbation Stochastic Approximation for Real-time Optimisation of Model Predictive Control”, *Proceedings of the 1<sup>st</sup> Industrial Simulation Conference (ISC’2003)*, Valencia, Spain, EUROSIS Editors: 533–537.
- [32] F.J. Vázquez-Abad, V. Krishnamurthy, K. Martin and I. Baltcheva, “Self Learning Control of Constrained Markov Chains – A Gradient Approach”, *Proceedings of the 41<sup>st</sup> IEEE Conference on Decision and Control*, Las Vegas, December 2002: 1940–1945.
- [33] F.J. Vázquez-Abad and V. Krishnamurthy, “Self Learning Call Admission Control for Multimedia Wireless DS-CDMA Systems”, *Proceedings of the 6-th WODES*, published by the IEEE Computer Society, Zaragoza, October 2002: 399-404.
- [34] F.J. Vázquez-Abad and I. Baltcheva, “Intelligent Simulation for the Estimation of the Uplink Outage Probabilities in CDMA Networks”, *Proceedings of the 6-th WODES*, published by the IEEE Computer Society, Zaragoza, October 2002: 405-410.
- [35] L. Andrew and F.J. Vázquez-Abad, ”Filtered Gibbs sampler for estimating blocking probabilities in product form networks”, *Proceedings of the International Conference on Wireless and Optical Communications*, Editors: N.C. Beaulieu and L. Hesselink. Published by ACTA Press, July 2002: 527-532.
- [36] F.J. Vázquez-Abad, Arnaldo Rodríguez, Anton Ng, Robert Warfield and Moshe Zukerman, “Bridging Theory and Practice in Network Design using Web-based Simulation”, *Proceedings of the 12th Annual Conference, Australasian Association for Engineering Education (AaeE 2001)*, Queensland University of Technology, Brisbane, Australia, 26-28 September 2001: 40-45.
- [37] F.J. Vázquez-Abad and L. Zubieta, “Distributed stochastic approximation for adaptive frequency allocation in subway networks” *Proceedings 39-th IEEE Conference on Decision and Control*, Sydney, Australia, Dec 2000, Edited by IEEE Control Systems Society: 4729-4734.
- [38] B. Heidergott and F.J. Vázquez-Abad, “Weak Differentiation and Gradient Estimation for Discrete Event Driven Processes”, *Proceedings of WODES 2000*, Ghent, August 2000. In *Discrete Event Systems, Analysis and Control*, R. Boel and G. Stremersch Editors, Kluwer Academic Publishers, Boston: 433-440.

- [39] F.J. Vázquez-Abad and L. Andrew, “Filtered Gibbs Sampler for Estimating Blocking Probabilities in WDM Optical Networks”, *Proceedings of the 14th European Simulation Multiconference*, Ghent, May, 2000, D.Van Landeghem Editor, Published by the Society for Computer Simulation : 548–555.
- [40] F.J. Vázquez-Abad and L. Zubieta, “Generalizations of the surrogate estimation approach for sensitivity analysis via simple examples”, *Proceedings of the 38-th IEEE Conference on Decision and Control*, Phoenix Dec, 1999, Edited by IEEE Control Systems Society: 1796-1803.
- [41] F.J. Vázquez-Abad and Manuel Cepeda-Jüneman, “The Phantom SPA Method: an Inventory Problem Revisited”, *Proceedings of the 1999 Winter Simulation Conference*, P. Farrington, H. Nembhard, D. Sturrock and G. Evans, Editors : 1664–1669.
- [42] S. Yakowitz, P. L’Ecuyer, and F.J. Vázquez-Abad, “Adaptation and Dispersion in Global Optimization”, invited paper in *Proceedings of the Joint Statistical Meetings of the American Statistical Association*, Baltimore 1999.
- [43] L.G. Mason, F.J. Vázquez-Abad and B. Kamté, “Performance Studies of IP over ATM via Access Flow Controlled Virtual Networks”, *Proceedings of the IEEE ATM Workshop '99, "Opening the New Horizons toward Global Multimedia Services"* : 517-522.
- [44] F.J. Vázquez-Abad and D. Dufresne, “Accelerated Simulation for Pricing Asian Options”, invited paper, in *Proceedings of the 1998 Winter Simulation Conference*, D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan, Editors : 1493–1500.
- [45] F.J. Vázquez-Abad, “The Case of the Swapping and of the Disappearing Phantoms”, invited paper *Proceedings of WODES98*, Cagliari, August 1998, Edited by The Institute of Electrical Engineers, Great Brittan : 102–107.
- [46] L.G. Mason, F.J. Vázquez-Abad and B. Kamté, “IP Over ATM via Access Flow Controlled Virtual Networks”, in *Proceedings of ICON 1998, Interoperability of Networks for interoperable services*, Baltzer Science Publishers, vol 1/2-4 : 369-379.
- [47] F.J. Vázquez-Abad and K. Davis “An Empirical Study of Weak Convergence for Automatic Learning”, *Proc. IFAC-CIS Conference*, vol 2, Belfort, May 1997: 63–68.
- [48] F.J. Vázquez-Abad, P. L’Ecuyer and B. Martin, “On the Linear Growth of the Split-and-Merge Simulation Tree for a Multicomponent Model”, *Proc. IEE, WODES96*, Edinburg, August 1996, Edited by The Institute of Electrical Engineers, Great Brittan: 57–62.
- [49] Vázquez-Abad, F.J., Cassandras, C.G., Julka, V. ”Centralized and Decentralized Asynchronous Optimization of Stochastic Discrete Event Systems”, *Proc. 34th IEEE Conf. Decision and Control*, Washington, December 1995: 3632-3637.
- [50] Vázquez-Abad, F.J. (1995) “Virtual and Node Routing for Optimal Control of Production Rates in a Flexible Manufacturing Facility”, *Proc. INRIA-IEEE Conf. on Emerging Technologies and Factory Automation*, vol 3, Paris, October 1995: 207-217.
- [51] Vázquez-Abad, F., Jacobson, S.H. (1994) “Application of RPA and the Phantom Harmonic Gradient Estimators to a Priority Queueing System”, *Proc. 1994 Winter Simulation Conf.*, J.D.Tew, S. Manivannan, D.A. Sadowski and A.F. Seila, editors: 369– 376.
- [52] Vázquez-Abad, F., L’Ecuyer, P. (1994) “Simulation trees for functional estimation via the phantom method”, *Proc. of the 11th International Conf. on Analysis and Optim. of Systems, DES*, Lecture Notes in Control and Information Series 199. G. Cohen, J.-P. Quadrat, Eds. Springer-Verlag : 449-455.



- [53] Vázquez-Abad, F., Kushner, H.J. (1993) “The surrogate estimation approach for sensitivity analysis in queueing networks”, *Proc. of the 1993 Winter Simulation Conf.*, G.W. Evans, M.Mollaghasemi, E.C. Russel, and W.E. Biles, editors.: 347–355.
- [54] Vázquez-Abad, F., Mason, L.G. (1992) “Decentralized isarithmic flow control for packet-switched networks”, in *Proc. of the 7th ATRS*, Australia: 277-286 (also presented at the Canadian Conf. on Electrical and Computer Eng. 1992, Toronto).
- [55] Vázquez-Abad, F. (1992) “Sensitivity Analysis for stochastic DEDS: an overview”, II Simposio en Probabilidad y Procesos Estocásticos y Primer Encuentro México-Chile, Guanajuato. *Aportaciones Matemáticas, Notas de investigación*, No. 7: 163 - 182.
- [56] Vázquez-Abad, F., L’Ecuyer, P. (1991) “Comparing alternative methods for derivative estimation when IPA does not apply directly”, *Proc. of the 1991 Winter Simulation Conf.*, Nelson, B., Kelton, D., Clark, G. editors: 1004 -1011.
- [57] Vázquez-Abad, F. (1990) “On the convergence of Monte Carlo optimization via the derivatives of stationary measures”, *Proc. of the IV CLAPEM*, Mexico: 335 - 349.
- [58] Ruiz, R., Vázquez-Abad, F., Zelaya, E. (1986) “Modelo de asignación óptima de recursos destinados a la investigación en el área de la energía”, *Memoria del Simposio de Modelos Matemáticos para la Planeación Energética*, UNAM, SEMIP editors. Mexico.

## Monographs

- [59] Vázquez-Abad, F. (1989) *Stochastic recursive algorithms for optimal routing in queueing networks*. Ph.D. Thesis. Division of Applied Mathematics, Brown University, May 1989.
- [60] Gottlieb, D., Vázquez-Abad, F. (1989) *Numerical methods for solving partial differential equations*, Lecture Notes, Brown University.

## Technical reports

- [61] F.J. Vázquez-Abad and L. Zubietta, “Ghost simulation model for the optimisation of an urban subway system”, *Les Cahiers du GERAD* G-2003-74, November 2003.
- [62] L.H. Andrew and F.J. Vázquez-Abad, “Filtered and Setwise Gibbs Samplers for Teletraffic Analysis”, *Les Cahiers du GERAD* G-2003-53, August 2003.
- [63] F.J. Vázquez-Abad and V. Krishnamurthy, “Self Learning Control of Constrained Markov Decision Processes – A Gradient Approach”, *Les Cahiers du GERAD* G-2003-51, August 2003.
- [64] F.J. Vázquez-Abad and B. Heidergott, “Gradient Estimation for a Class of Systems with Bulk Services”, Tinberger Institute Discussion Paper TI2003-057/4, Amsterdam, <http://www.tinbergen.nl>, 2003.
- [65] F.J. Vázquez-Abad and Irina Baltcheva, “Performance of CDMA mobile networks via intelligent simulation; an example with heavy tailed distributions”, *Cahier GERAD* 2002-69, Montreal, December 2002.
- [66] B. Heidergott and F.J. Vázquez-Abad, “Measure Valued Differentiation for Stochastic Processes: The Random Horizon Case”, *Cahier GERAD* 2001-18, Montreal, May 2001.



- [67] Vázquez-Abad, F.J. and L.H. Andrew, “Simulation Methods for Estimation of Blocking Probabilities in Cellular Telecommunication Networks”, CUBIN Technical Report 2001-01-01. University of Melbourne, Australia 2001.
- [68] B. Heidergott and F.J. Vázquez-Abad, “Measure Valued Differentiation for Stochastic Processes: The Finite Horizon Case”, EURANDOM report 2000-033, Eindhoven, the Netherlands, Sept 2000.
- [69] Vázquez-Abad, F.J., Cassandras, C.G., Julka, V. “Centralized and Decentralized Asynchronous Optimization of Stochastic Discrete Event Systems”, Dept of Manufacturing Engineering Technical Report, Boston University 1997.
- [70] F.J. Vázquez-Abad and K. Davis “Strong Points of Weak Convergence: A Study Using RPA Gradient Estimation for Automatic Learning”, Rapport Technique No. 1025, Département d’iro, Université de Montréal, April 1996.
- [71] F.J. Vázquez-Abad and K. Davis, “Efficient Implementation of the Phantom RPA Method, with an Application to a Priority Queueing System”, Rapport Technique No. 989, Département d’iro, Université de Montréal, August 1995.
- [72] Vázquez-Abad, F., Mason, L.G. (1992) “Adaptive flow control under non-uniqueness of the optimal control”, rapport technique INRS-Télécommunications, No. 92-19.
- [73] Vázquez-Abad, F., Mason, L.G. (1992) “Decentralized adaptive flow control for packet-switched networks”, rapport technique INRS-Télécommunications, No. 92-09.
- [74] Vázquez-Abad, F., L’Écuyer, P. (1991) “Comparing alternative methods for derivative estimation when IPA does not apply directly”, rapport de recherche GERAD, No. G-91-30 (see [56]).
- [75] Vázquez-Abad, F., Kushner, H.J. (1990) “A surrogate estimation approach for adaptive routing in communication networks”, Brown University report LCDS/CCS, No. 90-2.
- [76] Vázquez-Abad, F. J. (1982) “Desviación de la ley exponencial para sistemas cuánticos”, Reporte IFUNAM No. 82, Instituto de Física, UNAM.

## In Preparation

- [77] G. Cohen, F.J. Vázquez-Abad and L. Andrieu, “Gradient Estimation for Probabilities: from Maliavin Calculus to MVD”, in preparation.
- [78] F.J. Vázquez-Abad, “Ersätz Estimation for Sensitivity Analysis: A Methodology”, in preparation.
- [79] F.J. Vázquez-Abad, B. Sansò and eloim Gutiérrez-Cabrera, “Efficient scheduling algorithms for OBS switches”, in preparation.

## Communications

- F.J. Vázquez-Abad “Intelligent simulation for estimating uplink outage probability in a slow-fading CDMA cellular model under power control”, *Sixth Annual Melbourne - Adelaide Teletraffic Workshop*, Grampians, VIC Dec 12-14 2001.

- F.J. Vázquez-Abad and B. Heidergott, “Measure Valued Differentiation for Markov Chains”, 11th INFORMS Applied Probability Conference, NY July 2001.
- B. Heidergott and F.J. Vázquez-Abad, “Gradient Estimation for Stationary Markov Chains”, 11th INFORMS Applied Probability Conference, NY July 2001.
- F.J. Vázquez-Abad and D. Dufresne, “Measure change in averaged options and Levy processes”, Optimisation Days, Montreal, May 2000.
- F.J. Vázquez-Abad and L.H. Andrew, “Filtered Gibbs Sampler for Performance Evaluation of Loss Networks”, Optimisation Days, Montreal, May 2000.
- F.J. Vázquez-Abad, “Examples of the Phantom SPA Method”, 7th INFORMS Computing Society Conference on OR and Computing Tools for the New Millennium, Cancún, Mexico, January 2000.
- F.J. Vázquez-Abad, “Perturbation Methods for Risk Analysis: Application of the Virtual RPA Method for Non-Homogeneous Poisson Processes”, 10th INFORMS Applied Probability Conference, Ulm, July 1999.
- F.J. Vázquez-Abad, “Comparison of Three Simulation Methods to Estimate Ruin Probabilities in Insurance”, APORS Conference, Melbourne, December 1997.
- P. L’Ecuyer, B. Martin, F.J. Vázquez-Abad “Stability Results and Functional Estimation for Multicomponent Age-Replacement Policies”, 9th INFORMS Applied Probability Conference, Boston, July 1997.
- F.J. Vázquez-Abad, “Adaptive Control of DES Using Stochastic Approximation”, 9th INFORMS Applied Probability Conference, July 1997.
- F.J. Vázquez-Abad, “Sensitivity Estimation via the Phantom RPA Method”, Optimization Days, Montreal, May 1997.
- F.J. Vázquez-Abad, “Importance Sampling and RPA for the Estimation of Sensitivities of rare Events”, Optimization Days, Montreal, May 1997.
- F.J. Vázquez-Abad, “Phantom RPA Estimators of the Sensitivity under Threshold Controls”, IASIO Conference in Honor of Prof CR Rao, Montreal, Nov 1996.
- F.J. Vázquez-Abad, “Gradient-Based Stochastic Approximation Methods for Automatic Learning”, IV Bernoulli World Congress, Vienna, 1996.
- F.J. Vázquez-Abad, “A Survey of Weak Convergence of Stochastic Approximations for Automatic Learning”, Optimization Days, Montreal, May 1996.
- F.J. Vázquez-Abad and K. Davis, “A Comparative Study of Weak Convergence using LR and RPA for a Flexible Machine” Optimization Days, Montreal, May 1996.
- C.G. Cassandras and F.J. Vázquez-Abad, “Weak Convergence of Decentralized Asynchronous Stochastic Approximation Algorithms”, INFORMS Spring National Meeting, Washington D.C., May 1996.
- P. L’Ecuyer, B. Martin, and F.J. Vázquez-Abad, “Functional Estimation of the Expected Cost for Multicomponent Age-replacement Policies”. INFORMS Spring National Meeting, Washington D.C., May 1996.
- K. Davis and F.J. Vázquez-Abad, “On-line Routing and Flow Control for ATM Multimedia Networks” INFORMS Spring National Meeting, Washington D.C., May 1996.

- Vázquez-Abad, F.J. “On the convergence of gradient-based on-line optimization”, INFORMS Spring National Meeting, Los Angeles, April 1995.
- Vázquez-Abad, F., L’Ecuyer, P. “The phantom method for functional estimation”, ORSA/TIMS Joint National Meeting, Boston, April 1994.
- Vázquez-Abad, F. “Machine learning algorithms for teletraffic automated control”, ORSA/TIMS Joint National Meeting, Phoenix, Oct 1993.
- Mason, L.G., Pelletier, A., Vázquez-Abad, F., Cotton, M. “Isarithmic flow control and adaptive routing in high speed data networks”, CITR Annual Research Conf., Montréal, August 1993.
- Vázquez-Abad, F. “Surrogate estimation for Monte-Carlo optimization in queueing networks”, Optimization Days, Montréal, May 1993.
- Vázquez-Abad, F. “General properties of adaptive flow control algorithms for the isarithmic scheme”, CRM Workshop on Stochastic Control, Montréal, Nov 1992.
- Mason, L.G., Pelletier, A., Vázquez-Abad, F. “Self-optimizing isarithmic control for packet-switching networks”, CITR Annual Research Conf., Le Chantecler, May 1992.
- Vázquez-Abad, F., Mason, L.G. “Learning automata control schemes with unique and non-unique limit points under non-uniqueness of the optimal control”, Optimization Days, Montréal, May 1992.
- Vázquez-Abad, F., Mason, L.G. “Decentralized adaptive isarithmic flow control for packet-switched networks”, Second ORSA Telecom Conf., Boca Raton, March 1992.
- Brémaud, P., Vázquez-Abad, F. “On the pathwise computation of derivatives with respect to the rate of a pointprocess: the phantom RPA method”, Optimization Days, Montréal, May 1991.
- Brémaud, P., Baccelli, F., Vázquez-Abad, F. “Virtual and phantom customers in sensitivity analysis for point processes”, ORSA/TIMS Special Interest Conf. on Appl. Prob., Monterey, Jan 1991.
- Vázquez-Abad, F. “Stochastic recursive algorithms for optimal routing in queueing networks”, Optimization Days, Montréal, May 1990.

## Addendum: Research Contribution

### Statement

My research deals primarily with *adaptive control* and *efficient simulation* of stochastic dynamical systems, mostly *discrete event systems*. I am interested in developing self-optimizing algorithms for dynamic reconfiguration of telecommunications networks, adjustment of production rates and inventory policies in manufacturing facilities, frequency allocation in public transportation networks, and in methods for efficient simulation for finance and risk assessment problems. Automatic learning is composed of three fundamental steps:

- **Measuring performance.** The capability of identifying the performance of complex systems is an important subject in multiobjective optimization. Advanced simulation methods provide a viable way for solving this problem, especially for large systems.
- **Understanding the impact of actions.** Many traditional learning methods use estimation to fit parameter metamodels. Instead, the capability of measuring the impact of the actions can be translated into the estimation of sensitivities, improving the overall learning rate.
- **Capacity to react to the measurements.** Upon measuring the impact of the actions, control agents must react and adjust their strategies accordingly, in order for learning to take place. Stochastic versions of gradient search methods can be used for the updates (stochastic approximation) for convex problems. For complex problems, functional estimation for global convergence must be incorporated to the updating mechanisms.

### Most Significant Research Contributions

My most significant contributions can be described in terms of the following categories of theoretical contributions (references are to the corresponding publications).

- *Stochastic Approximation*
- *Sensitivity Analysis*
- *Ersatz or Surrogate Estimation*
- *Functional Estimation*
- *Advanced Simulation Methods*

Preliminary versions of several publications are available from my web site.

**Stochastic Approximation:** Let  $J(\theta)$  be a cost function, where  $\theta \in \mathbb{R}^d$  is a control parameter, and seek the optimal value:  $\theta^* = \arg \min_{\theta \in \mathbb{R}^d} J(\theta)$ . Newton-like methods for optimisation use the recursion  $\theta_{n+1} = \theta_n - \epsilon_n \nabla_{\theta} J(\theta_n)$ . If  $J(\cdot)$  is locally convex around the global minimum, the Capture Theorem establishes that  $\lim_{n \rightarrow \infty} \theta_n = \theta^*$ , when the initial point is in a neighborhood of  $\theta^*$  and the step sizes satisfy  $\epsilon_n \rightarrow 0, \sum_n \epsilon_n = +\infty$ . A more powerful tool for analysis, known as the ODE method, rewrites the update recursion as an approximation to an ODE. Then the piecewise constant interpolation of the sequence, which is a process, converges (in functional space) to the solution of the ODE:  $\vartheta'(t) = -\nabla_{\theta} J[\vartheta(t)]$ , and this holds also for the case where the step size is constant, under some boundedness assumptions for the gradient of the cost function. This result implies that the accumulation points of the sequence are stable points of the ODE and recovers the usual Capture Theorem.

Stochastic approximation is the stochastic version of the gradient method, when one assumes that  $J(\theta)$  is an average cost function of a stochastic system, or that the observations of the gradient are noisy. Consider the recursion  $\theta_{n+1} = \theta_n - \epsilon_n Y_n(\theta_n)$ . The main questions when studying systems under uncertainty are:

- under what assumptions on the noisy measurements  $\{Y_n\}$  is the control sequence is still asymptotically optimal?
- in what sense will the control sequence converge?
- can the procedure be adapted to decentralized operation?

For the problem of on-line learning it is required that the step sizes not converge to zero, and only *weak convergence* of the interpolations to the limit ODE can be shown. My most important contribution is in [15], where we provide the answer to the first question for a large number of dynamic stochastic systems. [14] gives the first proof of asymptotic optimality of learning automata under a stochastic environment, which had been conjectured in previous work and acknowledged as a difficult problem. In [12] we focus on the third question. With our methodology, the proofs of asymptotic optimality for asynchronous operations help design the appropriate minimal information exchange between distributed control agents. Our method allows the identification of the appropriate adjustments for adaptive control.

Our latest developments focus on self-optimised *Markov Decision Processes*, where we assume no knowledge of the underlying Markov transition kernel. Most importantly, we have studied the problem of optimisation under stochastic constraints of the form:

$$\theta^* = \arg \min_{\theta \in \Theta} J(\theta),$$

where  $\Theta$  is a set defined through inequalities of the form  $G(\theta) \leq 0$ , where  $G(\theta)$  is an invariant average at control value  $\theta$ . In [22] we analyse the implementation of the gradient estimation methods for primal dual, gradient projection and Lagrange multipliers methods for constrained optimisation. We identify the necessary conditions for the algorithms to converge and explain why these conditions may hinder the rate of convergence. Although we have worked the results for MDP's, the main ideas are general and we may be able to answer an important open question for real-time control by means of a fully automated scheme that finds the appropriate trade-off between fast tracking and suboptimality.

**Sensitivity Analysis:** Estimation of gradients of stationary averages is a difficult and important problem both for on-line as well as off-line optimization. The goal is to estimate the gradient  $\nabla_{\theta}J(\theta) = \nabla_{\theta}\mathbb{E}[L(Z_1(\theta), \dots, Z_N(\theta))]$ , where  $\{Z_n(\theta)\}$  is a process with state space  $S \subset \mathbb{R}^m$ ,  $\theta \in \mathbb{R}^d$  is a control parameter, and  $L$  is a cost functional.

- is there a method that works well for a given cost for a wide class of distributions of the process?
- is there a method that works well for a wide class of costs?
- how can derivative estimation be made efficient?

Under continuity assumptions, the stochastic derivative  $\frac{d}{d\theta}L[Z_1(\theta), \dots, Z_N(\theta)]$  is unbiased for the gradient and is known as the IPA (**infinitesimal perturbation analysis**) method. This methodology measures well to the first challenge above, but requires continuity: recent research has focused on the difficult and realistic case where discontinuities occur. A dual approach to this pathwise analysis uses the weak topology to write  $J(\theta)$  in terms of the distribution  $F_{\theta}$  of the process:

$$\nabla_{\theta}J(\theta) = \nabla_{\theta} \int_S L(z_1, \dots, z_N) F_{\theta}(dz_1, \dots, dz_N).$$

The distribution  $F_{\theta}$  is called **weakly differentiable** if there is a function  $F'_{\theta}$  such that  $\nabla_{\theta}\mathbb{E}[h(L)] = \int_S h(\mathbf{z})F'_{\theta}(d\mathbf{z})$  for any continuous and bounded function  $h$ , which targets the second question above. Sometimes it is possible to express  $F_{\theta}$  in terms of densities, obtaining the so-called LR (**likelihood ratio**) method. Unfortunately most cost functionals of interest are not bounded and LR methods suffer from typically large variances. My expertise in both pathwise analysis and weak derivative methods led to an invitation to prepare the course in [2].

We introduced the Phantom RPA (**rare perturbation analysis**) method in [16], as a generalization of the phantom finite difference of my PhD thesis [59]. This method deals with discontinuities via a conditioning and has been cited by many other researchers in the Discrete Event Systems area. Generalizations of this method appear in [5, 51] and [11], and novel applications are in [6, 8] and [71]. Notably, the method can be seen as a particular application of the SPA (**smoothed perturbation analysis**), yet the smoothing exploits precisely the jump discontinuities of the cost functional  $L$  and is also a particular case of a **weak derivative** but there is no need to impose boundedness of the cost functional. Our most recent papers [?] and [?] extend the methodology and introduce the concept of **measured valued differentiation**. Not only have we extended the applicability of weak differentiation, but we give definite conditions for the methods even when the horizon  $N$  is a random stopping time. The most important breakthrough in our recent results [?, ?] is the establishment of a **product rule** of differentiation for Markov kernels. With it, it is possible to express derivatives of averages of functionals of a process in terms of the (much simpler) derivative of input distributions, as stated in [18]. We are currently working towards the creation of a library of weak derivatives of common input distributions to be incorporated into a simulation package. The potential applications for optimisation are numerous.

**Ersatz or Surrogate Estimation:** Adaptive control problems are important for realistic applications arising in telecommunication and transportation networks, manufacturing systems, etc. The model is a high dimensional discrete event system represented by a Markov chain  $\{Z_n(\theta)\}$  in a general state space of  $r$  dimensions, with control variable  $\theta \in \mathbb{R}^d$ . Often the cost function  $J(\theta)$  depends non-linearly on different **local cost** expectations at various components of the larger system.

Decentralized and asynchronous implementation of **stochastic approximation** requires evaluation of the gradient  $\nabla_{\theta} J(\theta)$ , which may prove elusive for most sensitivity analysis methods.

- **how to decompose the cost function in terms of local costs at various components?**
- **how to distribute the computation of derivatives?**
- **how to reconstruct the asynchronous information received at the control centers?**

In [75], we published the concept of *surrogate estimation* in a queueing network for a routing problem. It proposes to use the information on the sensitivities w.r.t. some *local variables* at each queue in order to approximate sensitivities w.r.t. the desired controls. Our routing examples in [53] showed that, in addition to decentralizing the control structure, a dramatic reduction in computational effort is achieved with this method. Generalizations of this approach are in [40], where a subway network and an ATM polling switch are used as model examples to show the ease of the application of the method. We are currently developing the methodology with analytic proofs for what we call the *ersatz estimators*. Our approach is constructive and we identify when the ersatz are exact estimators, otherwise bounds on the error can sometimes be estimated.

**Functional Estimation:** The model is that of a stochastic process under a certain control strategy, parametrized by a control vector  $\theta \in \mathbb{R}^d$ . For each value of  $\theta$  the process  $\{Z_t(\theta)\}$  is a **discrete event process** with a cost  $h(\theta, \omega) = L(Z_1(\theta, \omega), \dots, Z_N(\theta, \omega))$ . Usually, a single simulation is required to estimate performance or cost functionals of the form  $J(\theta) = \mathbb{E}[h(\theta)]$ .

The **surface response methodology** is a method to interpolate a number of such estimates at  $\theta_i, i = 1, \dots, r$  to approximate the function  $J(\theta)$  on an open set  $\theta \in \Theta \subset \mathbb{R}^d$ . For certain models it is possible to use one single trajectory  $\omega$  to simulate  $h(\theta_i, \omega), i = 1, \dots, r$ , known as **concurrent estimation** or “phantom” methodology.

- **computational effort too large, especially for  $d \gg 1$**
- **how to choose the points  $\theta_i$ ?**
- **how to choose the sample size for each  $\theta_i$ ?**

We extend the idea behind the phantom method, to create a method for functional estimation in [52]. The method uses a **single trajectory**  $\omega$  to estimate the whole function  $J(\cdot)$  over  $\Theta$  and we call it the **Split-and-Merge Simulation Tree**. In [48] and [9] we apply the method to an age replacement policy problem, with a theoretical analysis of the algorithmic efficiency modeling the simulation tree as a branching process. Surprisingly, the computational effort of our method can be shown to be much smaller than a worst case analysis would predict and it may overcome the curse of dimensionality. The contribution [9] received the **2000 Jacob Wolfowitz Prize for Theoretical Advances in the Mathematical and Management Sciences**.

Often functional estimation is required to seek  $\theta^* = \arg \min_{\theta \in \mathbb{R}^d} J(\theta)$  under multiple local minima or when the gradient is hard to estimate. In these cases it may not be feasible to use **sensitivity analysis** to drive a **stochastic approximation** procedure. Instead, most machine learning methods compare estimates at various values  $\theta_i$  in order to find the best one. In [7] we have addressed the last two questions above when  $\theta \in \Theta$  is a continuous variable.



**Advanced Simulation Methods:** The problem is that of estimating a performance measure of a DES process  $E[L(Z_1, \dots, Z_N)]$  by simulation, which can greatly help in the design of engineering systems or in establishing control strategies in finance and risk theory. An important problem is when nonzero values of  $L$  do not occur frequently, known as **rare event estimation**. One known technique is to apply a change of measure via **Importance Sampling**, which states:

$$\mathbb{E}[L(Z_1, \dots, Z_N)] = \int_S L(\mathbf{z}) F(d\mathbf{z}) = \int_S L(\mathbf{z}) R(\mathbf{z}, \theta) G_\theta(\mathbf{z})$$

where  $G_\theta$  is a different distribution and  $R(\theta)$  is the corresponding weight. Often  $G_\theta$  is obtained by a transformation of  $F$  and  $\theta$  is a parameter of the transformation, satisfying:

- **simulation of the process under  $G_\theta$  should be simple**
- **the variance of the estimator should be minimal**

The main problem with this approach is that for complex dynamics of the process  $\{Z_n\}$  the appropriate  $G_\theta$  is often hard to evaluate. Define  $J(\theta) = \text{Var}[S(Z)R(\theta, Z)]$  when the process  $Z = \{Z_n\}$  follows the distribution  $G$ . In [44] we propose to use **stochastic approximation** to find the **optimal simulation parameter**:  $\theta^* = \arg \min_{\theta \in \mathbb{R}^d} J(\theta)$ . Evaluation of the gradient is done with **sensitivity analysis methods** concurrently with the estimation. Our method can achieve optimal performance with little extra effort, and we call it **accelerated simulation**.

**Applications:** We have applied the change of measure idea to the estimation of the probability of ruin and its derivatives in [6, 8] and to estimation of blocking probabilities in WDM and cellular networks in [4]. In [39] we have looked at the problem of estimating blocking from a different perspective, using **Markov chain Monte Carlo** methods to overcome the curse of dimensionality imposed by realistic sized network models. A summary of simulation methods for loss networks is in [67].

## Current Research Plan

**Main objective:** integrate the methodology of ersatz estimation, local sensitivities with phantom computations or accelerated simulations, and the weak convergence results for asynchronous components, in order to develop intelligent control mechanisms that track global optimality.

We call these mechanisms “intelligent”, in analogy with biological systems: global information about the system’s goal for performance improvement is not physically localized, but rather lies in the collective coherent behavior of its rather simple components. It is in these mechanisms that the capacity for learning and adaptation resides.

In order to accomplish our long term goals, we are currently working on shorter term projects via applications of learning mechanisms to realistic problems:

- *Scalable Window Flow Control.* Completion of the project of isarithmic flow control for IP over ATM reported in [46, 43], integrating the Self-Optimized methodology in a decentralized operation. In collaboration with Mason (NTU Singapore). The scheme uses information by geographical zones and broadcasts average delay and throughput to adjacent zones. Each zone has a permit-based flow control using a fixed number of permits. The network optimises these numbers according to congestion information. Scalability follows from the hierarchical zonal structure, yet the overall scheme achieves good performance and it is adaptive.
- *Agile Optical Networks.* In collaboration with Sansò (Polytechnique, Montreal) and Girard (INRS-Telecom, Montreal). Strategic research project sponsored by Nortel and NSERC. Many important questions on design and on-line control arise in the study of OBS networks. I am involved in the modeling and simulation of optical burst switching (OBS) networks, in addition to the study and design of adaptive flow control and routing. We plan to study first the impact of software engineering for efficient scheduling algorithms, in collaboration with Tucker and White (Melbourne). We also plan to compare the application of flow control methods such as the isarithmic control, “clamp” and common implementations of TCP/IP on the network layer, in collaboration with Hanly, Mukhtar and Andrew (Melbourne). This is the topic of research for Irina Baltcheva (Montreal).
- *Optimisation of Markov Decision Processes.* Adaptive control of MDP’s via the weak derivative formulation in [?] using stochastic approximation. Applications include optimal search techniques for GSM cellular networks and admission control problems. in telecommunication networks. With Krishnamurthy (UBC). This is the topic of research for Katerine Martin (Montreal), who will focus on optical networks under differentiated service.
- *Transportation Systems.* We propose to complete the problem of optimal frequency allocation for a subway system mentioned in [37] and extend it further to incorporate bilevel programming when passengers change their behaviour in response to changes in policies. Collaboration with Heidergott (TU Eindhoven) and Zubieta (Bishops University).