Curriculum Vitae

Dejan Milutinović

Department of Mechanical Engineering and Materials Science
Duke University
E-mail: dejan.m@duke.edu, Webpage: www.duke.edu/~dm75

Office address:
Department of **M**echanical **E**ngineering and **M**aterials **S**cience
Duke University, Box 90300, 144 Hudson Hall, Durham, NC 27708-0300
Phone: +1-919-660-5296, Fax: +1-919-660-8963

EDUCATION

Ph.D. in Electrical and Computer Engineering, 2004
Instituto Superior Tecnico, Technical University of Lisbon, Portugal
Thesis: Stochastic Model of Micro-Agent Populations

M.Sc. Control Systems (pre-Bologna) 1999
Note: Average mark 10.0 (scale 0 – 10.0)
Department of Electrical Engineering, University of Belgrade, Yugoslavia
Thesis: Digital Controller With Parameter Estimation

Dipl.-Ing. Electronics and Control (five-year university degree) 1995
Note: Average mark 9.1 (scale 0 – 10.0), top 5% student
Department of Electrical Engineering, University of Belgrade,Yugoslavia

AWARDS AND GRANTS

National Research Council (NRC) Associateship Award to carry out 2009
independent research supported by Army Research Office, NC, USA

Short Term Innovative Research (STIR) Award for research on Stochastic 2008
Control of Multi-Robot Systems, Army Research Office, NC, USA (~$50k)

1st runner-up for the best PhD thesis of the European Robotics, 2006
"Georges Giralt PhD Award", 5th edition, given by
The European Robotics Research Network (EURON); the network
is established by the leading European research institutions that work in
Robotics and it includes **190 institutions from 28 countries**

Grant recipient of the Foundation of Science and Technology, Portugal 2001-2004

Grant recipient of the Institute for Systems and Robotics, Lisbon, Portugal 2000

Grant recipient for outstanding students of the Foundation of the Ministry 1990-1994
of Education, Republic of Serbia

WORK EXPERIENCE

National Research Council Research Associate 2009
Army Research Office (ARO), NC, USA

Postdoctoral Researcher, Mechanical Engineering and 2008
Materials Science Dept., **Duke University, Durham, NC**

Postdoctoral Researcher, Computational Immunology, 2006-2008
Biostatistics and Bioinformatics Dept., **Duke University, Durham, NC**

Postdoctoral Researcher, Theoretical Biology Department, 2004-2006
School of Biology, **Utrecht University, The Netherlands**

PhD student, Institute for Systems and Robotics, 2000-2004
Instituto Superior Tecnico, **Technical University of Lisbon, Portugal**

External consultant, Coreworks Ltd., Lisbon, Portugal 2000-2001

Scientific engineer, Mihajlo Pupin Institute, Belgrade, Yugoslavia 1995-2000

Teaching Experience:
- Guest Lecturer, Robot Control and Automation, Department of Mechanical Engineering and Materials Science, Duke University; fall 2007
- Teaching Assistant, Dynamic Stochastic Estimation, Prediction and Smoothing, Instituto Superior Tecnico, Technical University of Lisbon Portugal fall 2002

Reviewer : Journal of Royal Society, Journal of Theoretical Biology, Journal of Mathematical Biology, Mathematical Biosciences, Engineering Applications of Artificial Intelligence;
2008 Edition of the Autonomous Agents and Multi-Agent Systems (AAMAS) conference, Robotics Track.
2008 Edition of the International Symposium on Flexible Automation (ISFA), 47th IEEE Conference on Decision and Control

Area of expertise: Stochastic Dynamical Systems and Statistical Signal Processing: modeling, parameter/state estimation, prediction and control. Data/sensor fusion. Multi-Agent Systems/Robotics. Optimal Control. Partial Differential Equations. Hybrid and Discrete event Systems. Systems Biology/Immune system. Development and application to: immune system, multi-agent systems, distributed/large-scale systems. Industrial experience in real-time computer control for power and water supply systems, and design of high sensitive/low noise instrumentation.

SKILLS

Programming Languages: C, C++, Java, Tcl/Tk, Pascal, Fortran, Basic, Assembler

Operating systems: Unix, Dos, Windows NT/95/98;

Microcontrollers: 8051, 80196, 68HC11

Standard software: Matlab, Simulink, Simnon, Tutsim, Spice, Mcap

Languages: English, Russian, Portuguese (basic), Dutch (basic), Serbo-Croatian (M.T.)

ACADEMIC PROJECTS

Quantitative Models of the Immune System Dynamics: Modeling and parameter identification of cells interactions. This includes: stochastic modeling of cellular interactions based on the distributions obtained by flow cytometry [1,6,15], data from virus-infected mice [4], cells division [5,8,9], design of biological experiments [18].

Modeling and Control of a Large-Size Robotic Population: The Stochastic Hybrid Automaton model. The state probability density function of this model is described by a system of partial differential equations (PDE). It provides the robots' distribution prediction over the operating space and the control of the distribution shape. Numerical solution for PDEs, Minimum Principle for PDEs, Numerical optimal control [1,7,16].

Self-organized behavior and information processing of multi-agent systems: Complementary study of biological and robotic multi-agent systems in order to model/design self-organized behavior and information processing of multi-agent systems. Modeling and analysis of biochemical pathways, stochastic strategies for control of multi-robot systems [3,13], mobile multi-sensor systems (NRC award), spatio-temporal estimation from biological cell motility imaging [2,12,14].

Modeling Robotic Tasks Using the Petri Nets: Linux server designed to provide Petri net execution of robotic tasks. Linux driver for Puma robot: Linux OS, C/C++. Real time software written to drive 6 joint manipulator Puma560. It contains 6 PID servo loops with the compensation of gravitational terms [17].

Digital Controller with Parameter Estimation: for Experimental Plant at the Department of Agriculture University of Belgrade: 80c196 microcontroller, Real Time Executive iDCX96. Original algorithm and easy tuning procedure make this controller suitable for experimental plants. The experimental plant is mostly in use for drying plants. **Role:**Design and implementation of self-tuning control algorithm [28,31].

Active Control of Frame Vibration: The feedback control of concrete structures that provides the vibration rejection. In this study we used a realistic example to estimate the intensity necessary for actuator force and changes in dynamical characteristics of the structure [11,19,20,25,26].

***Note: Numbers in square brackets refer to corresponding items in the list of publications**

INDUSTRIAL PROJECTS

Automatic Generation Control Software for the Power System of Serbia:View6000 SCADA (System Control And Data Acquisition) system, Unix (Linux/AIX) OS, Server/Client application, TCP/IP. This Real Time Control Software package send production demand to power plants based on measurement of frequency and power flows through power system interchange links.
Role: Negotiation of the software design and software development group leading.

DIGIAUDIO: FPGA development kit exclusively made for Digital Audio compliant with the Xilinx free WebPack FPGA design software: A/D(96kHz), D/A(192kHz), 24bit, SPDIF- AES/EBU I/Os, on-board clock generator and PLL for clock synthesis and synchronization with external word clock. Application: digital audio standard I/O interfaces, format converters, sample rate converters, audio effects processors,etc.
Role: Hardware design, PCB layout and prototyping.

Energy Management System (EMS) software for the water supply system of West Serbia, "Rzav"-Arilje: View6000 SCADA a Linux OS. This software calculates an optimal number of working pumps and valves position in the water supply system.
Role: Software development with the main responsibility for control algorithm, user interface and communication with the SCADA.

Chlorine Concentration Measuring/Controller Device for water treatment plants: 8051 microcontroller.
Role: Design of the high sensitive/low noise interface electronics between chlorine detector and A/D converter; the hardware design, user interface and control software.

Automatic Weighing System: C/C++, Clipper. Data base software that collects data from the electronic weighing device, which measures the weight of goods transported by trucks. The software provides the supervision of working persons, protects the data from illegal use and accidental loss. It automatically generates reports for the transporting company as a proof of weighing. The software allows for the cross validation of different data including trucks and drivers' personal data.
Role: Negotiation of the software design, software and data base design, communication protocol with the weighing device.

INVITED TALKS

1. Workshop on Multi-agent Systems in Biology and Robotics, 9th Conference on Artificial Life, ECAL 2007, Lisbon, Portugal

2. “Cell Populations and Robot Swarms”, Workshop on Collective Behaviors inspired by Biological and Biochemical Systems, IEEE 2007 International Conference on Robotics and Automation, ICRA 2007, Rome, Italy (given by my PhD supervisor, Prof. Pedro Lima)

3. “Stochastic Model of Micro-Agent Populations”, MITACS Math Biology Seminar 2006, University of British Columbia, Vancouver, Canada

4. “Fitting the LCMV CD8+ Data Based on Measurement and Process Noise Models”, 2006, Radiology Sciences Laboratory, Stanford University School of Medicine, USA

5. “Stochastic Model of Micro-Agent Populations”, 2005, Applied Mathematics Department, University of Twente, the Netherlands

6. “Stochastic Model of Micro-Agent Populations”, public talk organized at the Institute “Mihajlo Pupin”, Belgrade, Serbia and Montenegro, 2004

7. “Stochastic Micro-Agents”, Partial Differential Equations Seminar 2004, Mathematics Department, Instituto Superior Tecnico, Lisbon, Portugal

LIST OF PUBLICATIONS

Book

1. **Milutinovic D.**, Lima P. (2007): Cells and Robots: Modeling and Control of Large-Size Agent Populations", Springer Tracts in Advanced Robotics, *Springer* (abstract attached at the end of CV)

Journal publications

2. **Milutinovic D.,** Garg D. (2008): Force Localization and Mapping from Intravital Microscopy of Lymph Nodes, *submitted to Journal of Royal Society Interface*

3. **Milutinovic D.**, Kumar M., Garg D. (2008): Stochasticity as a Driving Force in Self-Organization of Robotic Swarm, *submitted to IEEE Transactions on Robotics* (*under revision*)

4. **Milutinovic D.**, De Boer, R. J. (2007): Process noise: an explanation for the fluctuations in the immune response during viral infection., *Biophysical Journal*, vol. 92, pp. 3358-67

5. Ganusov V. V., **Milutinovic D.,** De Boer R. J. (2007): IL-2 regulates expansion of CD4 T cell populations by affecting cell death: insights from modeling CFSE data. *Journal of Immunology,* vol. 179, pp 950-957

6. **Milutinovic D.**, Carneiro J., Athans M., Lima P. (2007): Modeling dynamics of cell population molecule expression distribution, *Nonlinear Analysis: Hybrid Systems ,* vol. 1, pp. 81-94

7. **Milutinovic D.**, Lima P. (2006): Modeling and Optimal Centralized Control of a Large-Size Robotic Population, *IEEE Transactions on Robotics*, vol. 22, No. 6, pp. 1280-1285

8. De Boer R. J., Ganusov V.V., **Milutinovic D.**, Hodgkin P.D., Perelson A.S. (2006): Estimating lymphocyte division and death rates from CFSE data, *Bulletin of Mathematical Biology*, vol. 68, pp. 1011-1031

9. Dowling M. R., **Milutinovic D**., Hodgkin P.D. (2005): Modelling cell lifespan and proliferation: Is likelihood to die or to divide independent of age?, *Journal of the Royal Society Interface*, vol. 2, No. 5, pp. 517 - 526

10. Carneiro J., Paixão T., **Milutinovic D.**, Sousa J., Leon K., Gardner R., Faro J. (2005): Immunological Self-Tolerance: Lessons from Mathematical Modeling, *Journal of Computational and Applied Mathematics*, vol. 184, pp. 77-100

11. Furundzic S., **Milutinovic D.** (2000): Active Structural Control of Frame Vibrations (in Serbian), *Materijali i Konstrukcije*, vol. 43 (No.1-2), pp. 20-27

Conference publications

12. **Milutinovic D.**, Garg D. (2008): Parameters and Driving Force Estimation of Cell Motility via Expectation-Maximization (EM) Approach, *submitted to American Control Conference* 2009, St. Louis, Missouri, USA

13. Kumar M., **Milutinovic D.**, Garg D. (2008): Role of Stochasticity in Self-Organization of Robotic Swarms, *Proceedings of American Control Conference* 2008, Seattle, Washington, USA

14. **Milutinovic D.** (2007): Force Localization and Mapping in Immunology Context, *Proceedings of the Athans 70 Symposium*, Florida, USA

15. **Milutinovic D.**, Carneiro J., Athans M., Lima P. (2003): A Hybrid Automata Model of TCR Triggering Dynamics, *Proceedings of the 11th Mediterranean Conference on Control and Automation – MED 2003*, Rhodes, Greece

16. **Milutinovic D.**, Lima P., Athans M. (2003): Biologically Inspired Stochastic Hybrid Control of Multi-Robot Systems, *Proceedings of the 11th International Conference on Advanced Robotics – ICAR 2003*, Coimbra, Portugal

17. **Milutinovic D.**, Lima P. (2002): Petri Net Models of Robotic Tasks, *Proceedings of the 2002 IEEE International Conference on Robotics and Automation - ICRA 2002*, Washington, D.C., USA, vol. 4, pp. 4059-4064

18. **Milutinovic D.**, Athans M., Lima P., Carneiro J. (2002): Application of Nonlinear Estimation Theory in T-Cell Receptor Triggering Model Identification, *Technical Report RT-401-02,RT-701-02*, Institute for System and Robotics, Insituto Superior Tecnico, Lisbon

19. **Milutinovic D.**, Furundzic S. (1999): Active Structural Control of Frame Seismic Vibrations, *Proceedings of 16thIAARC/IFAC/IEEE International Symposium on Automation and Robotics in Construction-ISARC'99*, Madrid, Spain, pp. 631-636

20. Furundzic S., **Milutinovic D.** (1998): Frame Active Control, *Proceedings of 15th ECPD International Conference on Material Handling and Warehousing*, Belgrade, pp. 4.53-4.57

21. Jakupovic G., Tomca-Andrijanic N., **Milutinovic D.**, Cukalevski N. (2000) Organization and Implementation of a Software Package for Power System Generation Control, *Proceedings of XLIV ETRAN conference on Electronics, Telecomm. Comp. and Nuclear Engineering*, Soko Banja, Yugoslavia

22. Jakupovic G., Tomca-Andrianic N., **Milutinovic D.**,Cukalevski N. (2000): Software for Power System Control (in Serbian), *Proceedings of 10th symposium on Telecommunications and Control in Power Systems JUKO-CIGRE*, III&V.9

23. Jakupovic G., **Milutinovic D.**, Tomca-Andrijanic N., Cukalevski N. (1999): Functional design of AGC/IS software package ver.4.0, Document No FD200, Mihajlo Pupin Institute, Belgrade

24. Jakupovic G., Cukalevski N., **Milutinovic D.**, Tomca- Andrijanic N., (1999): AGC Programmer's reference ver.3.05, Doc. No. PU100, Mihajlo Pupin Institute, Belgrade

25. **Milutinovic D.**, Furundzic S. (1998): An Example of Frame Active Control, *Proceedings of XXV Yugoslav Symposium on Operational Research*, Belgrade, pp. 635-638

26. Furundzic S., **Milutinovic D.** (1998): Active Control of Frame Deformation (in Serbian), *Proceedings of XXV Yugoslav Symposium on Operational Research*, Belgrade, pp. 611-614

27. **Milutinovic D.**, Mitrovic M. (1998): Robust IMC controller for Feedback Linearized DC/DC Converter (in Serbian), *Proceedings of XLII ETRAN conference on Electronics, Telecommunications, Computers and Nuclear Engineering*, Belgrade, pp. 576-579

28. Jakupovic G., **Milutinovic D.** (1998): Robust Analysis of BI Parametrized PI Controller (in Serbian), *Proceedings of XLI ETRAN conference on Electronics, Telecommunications, Computers and Nuclear Engineering*, Belgrade, pp. 425-427

29. **Milutinovic D.** (1997): Applying Forecast in Optimal Control of Water Supply Systems (in Serbian), *Proceedings of XLI ETRAN conference on Electronics, Telecommunications, Computers and Nuclear Engineering*, Belgrade, pp. 460-463

30. **Milutinovic D.** (1997): Applying Forecast in Water System Control (in Serbian), *Proceedings of XXV Yugoslav Symposium on Operational Research*, Belgrade, pp. 825-828

31. Car A., **Milutinovic D.**, Papic B. (1996): NA_TREG86 BI controller with discrete model estimation (in Serbian), *Proceedings of XL ETRAN conference on Electronics, Telecommunications, Computers and Nuclear Engineering*, Belgrade, pp. 560-562

32. Filipovic V., **Milutinovic D.** (1996): Optimal Control of Water Production System "RZAV"-Arilje (in Serbian), *Proceedings of XL ETRAN conference on Electronics, Telecommunications, Computers and Nuclear Engineering*, Belgrade, pp. 508-510

REFERENCES

1) Prof. Pedro Lima, Institute for Systems and Robotics,
Instituto Superior Técnico, Torre Norte - 6.18
Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal
Phone: +351-21-841-8274
Fax.: +351-21-841-8291
e-mail: pal@isr.ist.utl.pt

2) Prof. Michael Athans, Professor Emeritus, Massachusetts Institute of Technology,
Institute for Systems and Robotics, Instituto Superior Técnico, Torre Norte, piso 7
Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal
Phone: +351-93-876-5186
e-mail: athans@isr.ist.utl.pt

3) Prof. Bruno Siciliano, Professor of Control and Robotics, PRISMA Lab, Dipartimento di Informatica e Sistemistica Universita` degli Studi di Napoli Federico II,
Via Claudio 21, 80125 Napoli, Italy
Phone: +39 0817683179
Fax: +39 06233226128
e-mail: siciliano@ieee.org

4) Prof. Rob de Boer, Utrecht University, Utrecht , Theoretical Biology,
Utrecht University, Padualaan 8, 3584 CH Utrecht, The Netherlands
Phone: +31-30-253-7560
Fax.: +31-30-251-3655
e-mail: R.J.DeBoer@bio.uu.nl

5) Prof. Devendra Garg, Mechanical Engineering and Materials Science Dept.
Pratt School of Engineering, Duke University, Box 90300 Hudson Hall,
Durham, NC 27708-0300, USA
Phone: +1-919-660-5330
e-mail:dpgarg@duke.edu

6) Prof. Manish Kumar, Department of Mechanical Engineering
629 Rhodes Hall, ML 0072, University of Cincinnati, OH 45221, USA
Phone: +1-513-556-4668
e-mail:kumarmu@ucmail.uc.edu

CELLS AND ROBOTS : MODELING AND CONTROL OF LARGE-SIZE AGENT POPULATIONS

Dejan Milutinović & Pedro Lima

Abstract of the monograph that appeared in Springer Tracts in Advanced Robotics Series, Springer

Cells and Robots is an outcome of the multidisciplinary research spreading over Biology, Robotics and Hybrid Systems Theory. It is inspired by modeling reactive behavior of the immune system cell population. Each cell is considered as an independent agent. The state of the agent is uniquely defined by discrete and continuous variables. Therefore, a Hybrid Systems modeling approach is applied and the relation between the individual agent dynamics and the observed population dynamics is investigated. Following statistical physics reasoning, we disclose the form of the mathematical structure behind this relation. In our modeling approach, there is no difference if the cells are naturally or artificially created agents, such as robots. This appears even more evident when we introduce a case study concerning a large-size robotic population scenario. Under this scenario, we also formulate the optimal control of maximizing the probability of robotic presence in a given region and discuss the application of the Minimum Principle for partial differential equations to this problem.

Simultaneous consideration of cell and robotic populations is of mutual benefit for Biology and Robotics, as well as for the general understanding of multi-agent system dynamics. Biological experiments involving cell populations are the real-life realization of systems with a large amount of agents, while large-size robotic populations can be considered as their mechanistic analogy. The robotic systems are usually made to be manipulated with a specific purpose, e.g. terrain exploration, and therefore, their modeling is closely connected with their control. Cells can also be engineered and their behavior controlled, so as to lead to significant advances in medicine.

The text of this monograph is based on the PhD thesis of the first author. The work was the second best in the 5th edition of Georges Giralt Award for the best European PhD thesis in Robotics, annually awarded by the European Robotics Research Network (EURON).

Keywords associated with the book: Multi-Agent Systems, Stochastic Hybrid Automata, Immune System, T-Cell population, Robotics, Agent Population Dynamics, Agent Population Optimal Control

Audience: The monograph is aimed at researchers and postgraduate students working in the area of Multi-Agent Systems, including natural and artificial agents, such as cells and robots, respectively. This includes areas of the immune system modeling, Computational Biology, Bio-Medical Engineering, Robotics, Nano-Robotics, molecular devices, nanotechnology, aero-space applications. The monograph includes results related to the stochastic hybrid systems and the application of the optimal control for partial differential equations. Therefore, it is also of interest to engineers and mathematicians working in the theoretical development of Control System Theory and its applications.