Taft Research Support Cover Sheet

Date of Application: 2/6/13

Name, Department, and Rank: Magda Peligrad
Department of Mathematical Sciences, Professor

Amount Requested: $11,794

Title of Research Project: Towards a theory of large random matrices with dependent entries

Time Period: July 2013-April 2014

Probable Results of Award (such as external funding, publications, and presentations):

External funding, publications and presentation

All Applications

- Project description (500-1000 words) & budget.
- Itemized Budget & Justification
- External funding history for the past 5 years
- A 2-page, recently updated curriculum vitae for researcher and other collaborators, if applicable

External Funding-Related

- Potential Grantors or Request for Proposals
- External grant proposal, if applicable
- Award letters, if applicable

Review Taft website for full application guidelines.

Other Funding Applied for or Received for this Research Project

Source	Amount	Status

Is this a joint application?

If "Yes", complete the following section for all participating faculty:

Name	Department	Rank	Award Percentage

If applying for a Cost-Share grant, please indicate whether or not Cost-Share is required by grant giving organization and/or the budget items are necessary for the project but not covered by grant.

Taft Grants Received in the Last Five Years

1. Type and Dates Research Support Cost Sharing Grant Application summer 2009
Amount $14,925
Project Title: Modeling Dependence via Martingale Approximation and Limit Theorems
Resulting publications
1. Central limit theorem started at a point for additive functional of reversible Markov Chains (with C. Cuny (2012). Journal of Theoretical Probability. 25, 171-188.
2. Conditional central limit theorem via martingale approximation (2010). Dependence in probability, analysis and number theory. Kendrick Press. 295-311.
3. Asymptotic Properties of Self-Normalized Linear Processes with Long Memory (with H. Sang) (2012). Econometric Theory, 28 1–22.
4. On the invariance principle under martingale approximation (with C. Peligrad) (2011). Stochastics and Dynamics 11, 1-11.
Presentations:
1. Central limit theorem for Fourier transforms for stationary processes. 1052 AMS meeting; 2009.
2. Limit Theorems via martingale approximation. Case Western Reserve University, Cleveland March 2010.

2. Type and Dates Research Support Cost Sharing Grant summer 2010
Amount $14,990
Project Title Martingale Approximation and Limit Theorems
Resulting publications
1. Rosenthal-type inequalities for the maximum of partial sums of stationary processes and examples (with F. Merlevède) (2010); to appear in Annals of Probability.
2. Central limit theorem for linear processes with infinite variance (with H. Sang) (2010); to appear in Journal of Theoretical Probabilities.
3. Central limit theorem for triangular arrays of Non-Homogeneous Markov chains (2012) Probability Theory and Related Fields 154, 409-428.

3. Type and Dates Research Support Cost Sharing. Summer 2011
Amount $12,414
Project Title Sharp Inequalities and Limit Theorem for Stochastic processes
Resulting publications
1. Some Aspects of Modeling Dependence in Copula-based Markov chains (2012); (with M.Longla); in press J. Multivaiate. Anal. 111 (2012), 234–240.
2. Exact Moderate and Large Deviations for Linear Processes (2012); (with H. Sang, Y. Zhong and W.B. Wu) revised for Statistica Sinica.
3. On the functional CLT for reversible Markov Chains with nonlinear growth of the variance (2012) (with M. Longla, and C. Peligrad) Journal of Applied Probability 49. 4 1091-1105.
Presentation
Exact asymptotic for linear processes Banff, Canada; October 2011. International Banff International Research Station

4. Type and Dates Travel for research Spring 2011
Amount $ 3410
Project: Title Sharp Inequalities and Limit Theorem for Stochastic processes
Resulting publications
- Almost sure invariance principles via martingale approximation (with F. Merlevède and C. Peligrad) Stoch. Proc. Appl. 122 (2012), 170-190.
Presentations

1. Central limit theorem for Nonstationary Markov Chains. “Nagaev lecture” Torun, Poland, March 2011.
2. Limit theorems for Markov Chains Dependence in Probability and Statistics. Luminy France. April 2011.

5. Type and Dates: Cost Sharing Grant June 2012-September 2012
Amount: $11,392
Project Title: Limit Theorem for Stochastic processes started from a point
Resulting Publications
1. A quenched weak invariance principle (with Jérôme Dedecker, and Florence Merlevède) (2012); revised for Annals of Institute Henri Poincare
2. Asymptotic properties for linear processes of functionals of reversible Markov Chains. (2013) To appear in "High Dimensional Probability VI: the Banff volume”, Progress in Probability Springer Basel AG Vol 66, 197-212.
3. Quenched Invariance Principles via Martingale Approximation (2013). To appear in The volume in honour of Miklos Csorgo's work. Springer in the Fields Institute Communications Series.
Presentations:
1. Martingale approximation and its applications. 2012 Universite of Paris-est Marne la Valee 2012.
2. Functional CLT for Linear Processes with Long Memory. Ecole central Paris, 2012.
3. Asymptotic Properties of Linear Processes with Long Memory. International Symposium on Asymptotic Methods in Stochastics, Ottawa Canada, 2012.

Besides the research and presentations supported by all these awarded Taft grants, they also greatly contributed to several successful applications submitted to governmental agencies, NSA and NSF.

Project Description:
Towards a theory of large random matrices with dependent entries

This is a request for research support, as seed money, for writing a proposal during the summer of 2013, to be submitted in the fall of 2013 to US Army Research Laboratory and to National Security Agency for consideration for funding.

In January 2013 I participated in a mini-course in random matrices, organized by the American Mathematical Society just before its annual meeting in San Diego. This mini-course featured lectures by the well-known specialists in the field. During this course I got informed about this fascinating and useful field of large random matrices. This interdisciplinary field has important applications to the statistical analysis of huge data set and multivariate statistics; in physics, concerning particle interactions; in number theory, the distribution of zeros of the Riemann zeta function; in engineering, for modeling the wireless communication channels. In this mini-course I found out that the most important and challenging open problem concerns the limiting spectral distribution of random matrices with dependent entries. So far the theory is very well understood only when the entries of a matrix are independent random variables.

Immediately after returning from this meeting, I had a visitor, Florence Merlevede, from University of Paris East, and together we started to attack this problem. It turns out that our experience of working with sequences of dependent data, especially the techniques we developed during the years, might play an essential role to attack this very difficult problem. The preliminary results are promising. We already started to develop some techniques for the complicated matrix model. We are confident that our ideas will lead to important discoveries in this filed.

The large matrix model requires the simultaneous treatment of many sequences of random variables that form a random field. Furthermore the problems studied are complex and involved and require a deep understanding of specific notions, such as limiting empirical spectral distribution, oscillations, Gaussian ensembles. The theory combines various subfields of mathematics: algebra, probability theory, complex analysis and ergodic theory.

To be able to continue working on these problems I would like to seek external support. The applications in the wireless communication channels, makes this subject of interest to several governmental agencies including US Army Research Laboratory and also National Security Agency. These are the places where the proposal will be sent if this Taft research support grant is awarded.

This grant will allow me, instead of teaching during the summer, to concentrate on studying all the background material in this field needed to write a successful proposal. A special attention will be given to various applications that would be of interest to the specific agencies. Then I intend to develop the methods we are going to use for the case when the variables which compose the matrix are dependent. So far, we found out that the best method to use involves several steps. First we shall apply a blocking technique that will have as a consequence the weakening the dependence structure making the far apart blocks of variables less dependent one of another. Then we shall develop a generalization of the so called Lindeberg's method which allows us to successively replace each vector of the matrix with another one containing well-behaved Gaussian variables. An extension of Lindeberg's method to vectors is feasible and can be successfully applied to the whole matrix. Then we have to analyze the new structure that will be facilitated by special properties of matrices with Gaussian entries.

The second component of the grant is the money requested to partial support the travel of Florence Merlevede to the University of Cincinnati for two weeks in the fall. We started together to work on this topic during her visit in January. Anytime we meet, we work intensively together and significant progress is achieved. We have written 17 joint papers and we have a book in progress. Her visit, in the fall of 2013, will contribute to the success of this and also future proposals. We are confident we can provide some breakthrough material in this new field of research for us.

Budget and budget justification

Salary		**$7500**
Benefits	29.25%	**$2194**
Travel		**$2100**
Total		**$11794**

Budget justification.

The amount 7500 represents about 2/3 of a month salary for the summer of 2013.
The amount 2194 represents the fringe benefits.
The amount 2100 will partially cover the travel for the collaborator Florence Merlevede from University. Paris east , Marne la Valle France to visit University of Cincinnati to help me working on this project. 14 days at $150 per day.

The budget of the grant will contain 1.5 month salary for 3 years period, travel, support for graduate students, benefits and 57% overhead. The estimate of the budget will be around $180,000.

External funding History Past 5 years

National Security Agency, PI	H98230-07-1-0016,	2007-2009	awarded
National Security Agency, PI	H98230-09-1-0005,	2009-2011	awarded
National Security Agency, PI	H98230-11-1-0135,	2011-2013	awarded
National Science Foundation, PI	DMS-1208237,	2012-2015	awarded

I have written 25 papers mentioning the outside support received in the last five years. These papers were the subject of 12 presentations, detailed in the short C.V. I also attached the last progress report submitted to National Security Agency.

Two NSF grants awarded for supporting United States participants in international conferences in 2008, 2009.

Other grants applied for but not awarded:

National Science Foundation in 2008 and 2010
National Security Agency in 2010

Curriculum Vitae (short). Revised February 2013

Magda Peligrad, Professor of Mathematics

Ph.D. in Mathematics, Center of Mathematical Statistics, Bucharest, Romania, 1980.
Last Academic Appointment: Professor, University of Cincinnati, 1991-present.

Grants and awards

Prior to 2000 I had 10 years continuous NSF awards. Also 8 years of NSA research grants 2004-2013 (active). A NSF grant 2012-2015.
5 Professional Development Grants, NSF Travel Grant, Taft Travel Grants, 2000, 2002.
Taft Competitive Fellowship award, 2003, Taft research supports 2004, 2007,Taft grant cost share 2005, 2008, 2009, 2011. Taft Research Seminar 2008.

Memberships and honors

Institute of Mathematical Statistics Representative to the Committee on Women in Mathematical Sciences 1989-1992.
Institute of Mathematical Statistics Fellow, elected 1995.
Faculty Achievement Award, 1996.
Distinguished Taft Professor at the University of Cincinnati starting June 2003.
Meeting in the honor of Magda Peligrad, Sorbonne, Paris 2010.

Activities

Referee for: Annals of Probability; Probability Theory and related Fields; Rocky Mountain J. Math.; Progress in Prob. and Stat. Birkhäuser, NSF Proposals, NSA proposals, J. of Multivariate Analysis, Stochastics, Stochastic Processes and their Applications, Statistics and Probability Letters, Annals of Statistics, Pacific J., Revue Roumain Math., Almost Sure Convergence in Prob. and Ergodic Theory, Canadian Journal of Statistics, J. of Theoretical Probability, Electronic Probability Journal, Annals of Institute Henry Poincare, Annals of the Institute of Mathematical Statistics, Applied Mathematics Letters, Journal of Applied Probabilities, Annals of Statistics.

-Associate editor the Journal of Mathematical Analysis and Applications, (2006-present).
-Co-editor of IMS volume on High Dimensional probabilities 2009.
-Co-editor of the Volume Dependence in probability, analysis and number theory. Kendrick Press. (2010).
-Served on one NSF panel in Probability Theory 2008.
- co-organizer of several Cincinnati Symposium on Prob. Th. and Applications, 2009.
- co-organizer for the meeting High Dimensional Probabilities V, Luminy France, 2008.
- co-organizer and the Conference in the memory of Walter Philipp, Graz Austria, 2009.
-co-organizer special sessions in AMS meetings.
- scientific secretary of the workshop on large deviations, Luminy, France, 2011

Invited Lectures since 2005

University of Rome 2, March 2005. University of Michigan, April 2005. Georgia Tech., November 2005. Universite de Rouen France, June 2007. Universite de Rennes 1 June 2007, France. 32st Conference SPA Urbana-Illinois 2007. Horowitz Seminar, Tel Aviv University, June 2008. Cincinnati Symposium, March 2009. BIRS Workshop on Stochastic Inequalities, Banff Canda, June 2009. Walter Philipp memorial conference in Graz, June17-20, 2009. Penn. State University, October 2009. Case Western Reserve University, Cleveland March 2010. Nagaev Lecture. Torun, March 2011. Workshop on dependence in probability and statistics, CRM Luminy, France, April 2011. BIRS Workshop on high dimensional probabilities. Banff Canada October 2011. Universite of Paris-est Marne la Valee 2012. Ecole central Paris, 2012. International Symposium on Asymptotic Methods in Stochastics, Ottawa Canada, 2012.

Selected publications after 2005, (from a total of 81)

-On the weak invariance principle for stationary sequences under projective criteria (with F. Merlevède). (2006). Journal of Theoretical Probabilities. Vol 19, 647-689.
-Recent advances in invariance principles for stationary sequences. (with F. Merlevède and S. Utev). (2006). Probability Surveys. Vol 3 1-36.
-Another approach to Brownian motion (with S. Utev). (2006). Stochastic Processes and their Applications 116, 279-292.
-Central limit theorem for stationary linear processes (with S. Utev). (2006) The Annals of Probability 34, 1608-1622.
-Invariance principle for stochastic processes with short memory (with S. Utev). (2006). IMS Lectures Notes and Monograph Series. High Dimensional probability 51. 18-32.
-A maximal L(p)- Inequality for stationary sequences and application (with S.Utev and W. B. Wu) (2007). Proc. AMS 135, 541-550.
-On fractional Brownian motion limits in one dimensional nearest-neighbor symmetric simple exclusion (with S. Sethuraman) (2008) ALEA, 4, 245-235.
-Moderate deviation for stationary sequences of bounded random variables (with J. Dedecker, F. Merlevède and S. Utev) (2009). Ann. Inst. H. Poincaré Probab. Statist. 45, 453-476.
-Functional Moderate deviation for triangular arrays and applications (with F Merlevède) (2009) ALEA 5, 3-20.
-Moderate deviations for linear processes generated by martingale-like random variables (with F. Merlevède) (2010) Journal of Theoretical Probabilities 23, 277-300.
-Bernstein inequality and moderate deviation under strong mixing conditions. (with F. Merlevède and E. Rio) (2010) IMS Collections. High Dimensional Probability V, 273-292.
-Conditional central limit theorem via martingale approximation. Dependence in probability, analysis and number theory. (2010) Kendrick Press. 295-311.
-Central limit theorem for Fourier transform of stationary processes. (with W. B. Wu) (2010) Annals of Probability 38, 2009-2022.
-A Bernstein type inequality and moderate deviations for weakly dependent sequences (with F. Merlevède and E. Rio) (2010) to appear in Probability Theory and Related fields 151, 435-474
-Invariance principles for linear processes. Application to isotonic regression. (with J. Dedecker and F. Merlevède) (2011) Bernoulli 17, 88-113.
-On the invariance principle under martingale approximation (with C. Peligrad) (2011); Stochastics and Dynamics 11, 1-11.
- On the functional CLT via martingale approximation (with M. Gordin) (2011) Bernoulli 17, 424-440.

-Central limit theorem started at a point for additive functional of reversible Markov Chains. (with C. Cuny) (2012). Journal of Theoretical Probabilities 25, 171-188.
-Asymptotic Properties of Self-Normalized Linear Processes with Long Memory (with H. Sang) (2012); Econometric Theory, 28, 2012, 1–22.
-Rosenthal-type inequalities for the maximum of partial sums of stationary processes and examples (with F. Merlevède) (2012); to appear in Annals of Probability. Pre-published on line.
-Central limit theorem for linear processes with infinite variance. (with H. Sang) (2012); to appear in Journal of Theoretical Probabilities.
-Central limit theorem for triangular arrays of Non-Homogeneous Markov chains. (2012) Probability Theory and Related Fields. 154, 409-428
- Exact Moderate and Large Deviations for Linear Processes; (with Hailin Sang, Yunda Zhong and Wei Biao Wu) (2012) Revised for Statistica Sinica
-Almost sure invariance principles via martingale approximation; (with F. Merlevède and Costel Peligrad). (2012) Stoch. Proc. Appl. 12 , 170-190.
-Some Aspects of Modeling Dependence in Copula-based Markov chains (with Martial Longla) (2012), J. Multiv. Anal 111, 234–240.
-On the functional CLT for reversible Markov Chains with nonlinear growth of the variance (with M. Longla, and C. Peligrad) (2012) Journal of Applied Probability 49. 4 1091-1105.
-A quenched weak invariance principle (with Jérôme Dedecker, and Florence Merlevède) (2012); under revision for Annals of Institute Henri Poincare
-Asymptotic properties for linear processes of functionals of reversible Markov Chains. (2013) To appear in "High Dimensional Probability VI: the Banff volume", Progress in Probability Springer Basel AG Vol 66, 197-212.
- Quenched Invariance Principles via Martingale Approximation (2013). To appear in The volume in honour of Miklos Csorgo's work. Springer in the Fields Institute Communications Series.

Two POST Ph.D. ASSOCIATE and six PhD students; the seventh in progress.

Army Research Laboratory Broad Agency Announcement for Basic and Applied Scientific Research

ARMY RESEARCH LABORATORY BROAD AGENCY ANNOUNCEMENT FOR BASIC AND APPLIED SCIENTIFIC RESEARCH

W911NF-12-R-0011

15 May 2012 – 31 March 2017

ISSUED BY:

U.S. Army Contracting Command-Aberdeen Proving Ground
Research Triangle Park Division
P. O. BOX 12211
Research Triangle Park, NC 27709-2211

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I. OVERVIEW OF THE FUNDING OPPORTUNITY:

INTRODUCTION

This Broad Agency Announcement (BAA), which sets forth research areas of interest to the Army Research Laboratory (ARL) Directorates and Army Research Office (ARO), is issued under the paragraph 6.102(d)(2) of the Federal Acquisition Regulation (FAR), which provides for the competitive selection of basic research proposals. Proposals submitted in response to this BAA and selected for award are considered to be the result of full and open competition and in full compliance with the provision of Public Law 98-369, "The Competition in Contracting Act of 1984" and subsequent amendments.

Research proposals are sought from educational institutions, nonprofit organizations, and commercial organizations for research in materials sciences; ballistics and aeromechanics sciences; information sciences; human sciences; survivability, lethality, and vulnerability analysis and assessment; chemistry; electronics; physics; environmental sciences; life sciences; mechanical sciences, mathematical sciences, computing sciences and network sciences. Proposals will be evaluated only if they are for scientific study and experimentation directed toward advancing the state of the art or increasing knowledge and understanding.

ARO has primary responsibility for ARL's extramural basic research programs, with specific research interests as described in Part II.A.2. The ARL Directorates, while having primary

responsibility for ARL's in-house research programs, also manage select extramural basic research programs. The research interests of the Directorates are described in Part II.A.1. Although ARL Directorates will consider funding proposals for extramural research programs, they can fund only a modest number of proposals in a single fiscal year. It should be noted that the ARL Directorates are highly interested in performing research in collaboration with other scientists and engineers. So, in addition to funding select external research projects, the ARL Directorates also have a strong interest in performing joint research with other organizations in the Directorates' core competency areas as described in this BAA. Inquiries regarding funding and/or collaborations should be directed to the listed Technical Point of Contact (TPOC).
Foreign owned, controlled, or influenced firms are advised that security restrictions may apply that could preclude their participation in these efforts. Before preparing a proposal, such firms are requested to contact the ARL Security and Counterintelligence Branch (301) 394-2444 concerning their eligibility. Pursuant to the policy of FAR 35.017 and supplements, selected Federally Funded Research and Development Centers may propose under this BAA.
PART II, Other Programs, addresses specific contributions to Conferences and Symposia and HBCU/MI support.
The Army has a long history of advocating and supporting research at historically black colleges and universities and minority institutions (HBCU/MI). We actively seek research proposals from HBCUs and MIs in full competition with all offerors who may submit proposals under this BAA. Proposals may be submitted at any time. We also encourage the inclusion of HBCUs and/or MIs as part of a consortium proposal or as subcontractors/ subgrantees to prime recipients.
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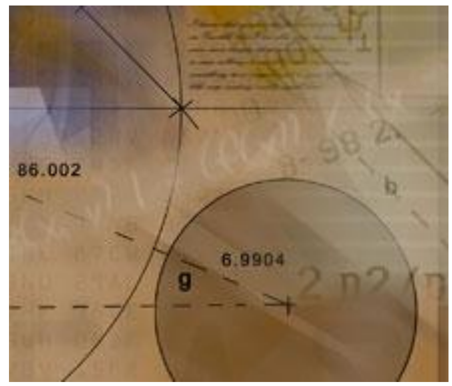
In order to conserve valuable offeror and Government resources and to facilitate determining whether a proposed research idea meets the guidelines described herein, prospective offerors contemplating submission of a white paper or proposal are strongly encouraged to contact the appropriate technical point of contact (TPOC) before submission. The TPOCs' names, telephone numbers, and e-mail addresses are listed immediately after each research area of interest. If an offeror elects to submit a white paper, it must be prepared in accordance with the instructions contained in PART III Section 3. Upon receipt, a white paper will be evaluated and the offeror shall be advised of the evaluation results. Offerors whose white papers receive a favorable evaluation may be contacted to prepare a complete proposal in accordance with instructions contained in PART III Section 5.
The costs of white papers and/or complete proposals in response to this BAA are not considered an allowable direct charge to any award resulting from this BAA or any other award. It may be an allowable expense to the normal bid and proposal indirect costs specified in FAR 31.205-18.
In accordance with federal statutes, regulations, and Department of Defense and Army policies, no person on grounds of race, color, age, sex, national origin, or disability shall be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving financial assistance from the Army.
Offerors submitting proposals are cautioned that only a Contracting or Grants Officer may obligate the Government to any agreement involving expenditure of Government funds. This BAA also applies to research proposals submitted to the RDECOM International Technology Centers.
For ARL Directorate Research Areas II.A.1, offerors should discuss the preferred performance period with the Technical Point of Contact (TPOC). For ARO's Research Areas II.A.2, it is

preferred that proposals are submitted to cover a 3-year period and include a brief summary of work contemplated for each 12-month period so that awards may be negotiated for an entire 3-year program or for individual 1-year increments of the total program.
All administrative inquires regarding this BAA shall be addressed to voice mailbox number 919-549-4375. Technical questions should be referred to the TPOCs shown following each research area of interest. When an inquiry is made, please clearly state your name, correct spelling, and
s Capital Cost of Money (FCCM) (DD Form 1861) is required.

Mathematical Sciences Program



The National Security Agency Mathematical Sciences Program (MSP) was started at NSA in 1987 in response to an increasingly urgent need to support mathematics in the United States. Indeed, the NSA realizes the mutual benefits of maintaining a vigorous academic community and is proud to offer grant funding and sabbatical opportunities for eligible faculty members through the MSP.

Grants for Research in Mathematics:

The MSP supports self-directed, unclassified research in the areas of Algebra, Number Theory, Discrete Mathematics, Probability, and Statistics. The program does not support research in cryptology. The Research Grants program offers three types of grants: the Young Investigators Grant, the Standard Grant, and the Senior Investigators Grant. More details are available on the MSP proposal submission website. Investigators must be U.S. citizens or permanent residents of the United States. Proposals should be submitted electronically by **October 15** via the MSP website. **Awards are made in the fall of the following year.** Questions about the program may be directed to MSPgrants@nsa.gov.

Conferences, Workshops, Special Situation Proposals:

The MSP supports conferences and workshops in the five subject areas named above. Average award for conferences and workshops is $15,000 - $20,000. The Special Situation Proposal category is for research experience for undergraduates or events that do not fall within the typical "research" conference format. In particular, MSP is interested in supporting efforts that increase broader participation in the mathematical sciences, promote wide dissemination of mathematics, and promote the education and training of undergraduates and graduate students. Proposals should be submitted electronically by **October 15** annually through the Proposal Submission Website.

Sabbaticals Program:

To obtain additional information about the MSP such as selection criteria, proposal preparation, grant descriptions, or proposal ideas, please call.

The MSP Sabbatical Program offers mathematicians, statisticians, and computer scientists the unique opportunity to work side by side with other NSA scientists on projects that involve cryptanalysis, coding theory, number theory, discrete mathematics, statistics, probability, and many other subjects. Sabbatical visitors must be U.S. citizens.

NSA Mathematical Sciences Program
Email: MSPgrants@nsa.gov Phone: 301-688-0400 Fax: 301-688-0697

Interim report NSA H98230-11-1-0135

Sharp inequalities and limit theorems for stochastic processes.

May 2011-November 2012
Magda Peligrad, University of Cincinnati

This report is an update of the previous annual report and also includes the new research completed or initiated since then as well as the research planned for the last six months period of this grant.

In the report period (three semesters) a significant progress has been made in obtaining sharp inequalities and limit theorems for stochastic processes. The results include inequalities for reversible processes, Rosenthal inequalities as well as sharp limit theorems for stochastic processes obtained via martingale approximation. They were developed in thirteen papers, of which eight were accepted for publication, published or pre-published on line (four of them, namely 1, 3, 4 and 5 below, acknowledge besides this grant the previous grant H98230-09-1-0005, when the research for these papers was initiated). Another five papers were submitted for publication and are under review. Some of these results were presented in six invited talks. Several new directions of research were initiated, including the study of the behavior of several new Metropolis Hastings algorithms.

The report is organized as follows: First, a list of research activities completed during the first three semesters of the grant is given and then, a brief description and the importance of some of the results are included. Finally, I point out the broader impact. A folder containing the papers published, in press or completed during the report period is attached.

(A) **Articles that have been published accepted and submitted for publication during the report period.**

1. Asymptotic properties of self-normalized linear processes with long memory (with Hailin Sang). (2012). Econometric Theory **28** 548-569. doi:10.1017/S026646661100065X http://arxiv.org/pdf/1006.1572.pdf

2. Almost sure invariance principles via martingale approximation (with Florence Merlevède and Costel Peligrad). (2012). Stoch. Proc. Appl. **122** 170-190. Doi 10.1016/j.spa.2011.09.004 http://arxiv.org/pdf/1103.6266.pdf

3. Rosenthal-type inequalities for the maximum of partial sums of stationary processes and examples (with Florence Merlevède). (2012); to appear in Annals of Probability. DOI: 10.1214/11-AOP694 http://arxiv.org/pdf/1103.3242.pdf

4. Central limit theorem for linear processes with infinite variance (with Hailin Sang). (2011); to appear in Journal of Theoretical Probabilities. DOI: 10.1007/s10959-011-0393-0 http://arxiv.org/pdf/1105.6129.pdf

5. Central limit theorem for triangular arrays of Non-Homogeneous Markov chains. (2012); Probability Theory and Related Fields. **154** 409-428 DOI: 10.1007/s00440-011-0371-6. http://arxiv.org/pdf/1012.6000.pdf

6. Some Aspects of Modeling Dependence in Copula-based Markov chains (with Martial Longla). (2012). Journal of Multivariate Analysis **111** 234–240. http://arxiv.org/pdf/1107.1794.pdf

7. Exact Moderate and Large Deviations for Linear Processes (with Hailin Sang, Yunda Zhong and Wei Biao Wu). (2012). Under review for Statistica Sinica. http://arxiv.org/pdf/1111.0537.pdf

8. On the functional CLT for reversible Markov Chains with nonlinear growth of the variance (with M. Longla, and C. Peligrad). (2012) Journal of Applied Probability. **49**.4 1091-1105. http://arxiv.org/pdf/1112.2751.pdf

9. A quenched weak invariance principle (with Jérôme Dedecker, and Florence Merlevède). (2012). Revised for Ann. Inst. H. Poincaré Probab. Statist. http://arxiv.org/pdf/1204.4554v1.pdf

10. Asymptotic properties for linear processes of functionals of normal or reversible Markov Chains. (2012). To appear in the proceedings volume of the Banff High Dimensional Probability Meeting in the Springer/Birkhauser Progress in Probability series. http://arxiv.org/pdf/1205.5575.pdf

11. Quenched Invariance Principles via Martingale Approximation (2012). Submitted to the volume in honour of Miklos Csorgo's work. Springer in the Fields Institute Communications Series.

12. Law of the iterated logarithm for the periodogram (with Christophe Cuny and Florence Merlevède). (2012). Submitted http://arxiv.org/pdf/1210.5032.pdf

13. The Selfnormalized Asymptotic Results for Linear Processes (with Hailin Sang). (2012). Submitted to The volume in honour of Miklos Csorgo's work. Springer in the Fields Institute Communications Series.

(B) **Additional research in progress**

1. On the variance of normal and reversible Markov Chains. (with Sergey Utev and George Deligiannidis.)

2. Research book project on Dependence Structures (with Florence Merlevède, Sergey Utev and George Deligiannidis.)

(C) **Lectures and talks to meetings based on these results during the report period.**

1. Central limit theorem for non-stationary Markov Chains. Nagaev Lecture. University of Torun Polland, 2011.

2. Limit theorems for Markov Chains. Dependence in Probability and Statistics. Luminy. 2011.

3. Exact asymptotic for linear processes. Invited presentation. International conference on: High dimensional probabilities. Banff Canada, October 2011.

4. Martingale approximation and its applications. Invited lecture. Universite of Paris-Est Marne la Valee, June 2012.

5. Functional CLT for Linear Processes with Long Memory. Invited lecture. Ecole Central Paris France, June 2012.

6. Asymptotic Properties of Linear Processes with Long Memory. Invited presentation. International Symposium on Asymptotic Methods in Stochastics, Ottawa Canada, July 2012.

(D) **Research visitors hosted.**

Florence Merlevède (for two weeks in 2011).

(E) **Concise description of the results.**

Papers 1 and 4 are dedicated to the study of linear processes with independent innovations with infinite variance. The functional form of the central limit theorem is obtained. The normalizer in this theorem is complicated, and depends to the level of truncation of the variables. To compensate for this inconvenience we develop the self-normalizers that are easily estimable from the observed data. Also in the context of linear processes paper 7 deals with exact deviations when this time moments higher than two are available. These results are extremely important for actuarial sciences. Paper 13 is a survey paper on the self-normalized invariance principles for linear processes reflecting the progress done in the last ten years in this direction.

In paper 3 we propose new Rosenthal-type inequalities for moments of order higher than two of the maximum of partial sums of stationary sequences, including martingales and their generalizations. The estimates of the moments are expressed in terms of the norms of projections of partial sums. The proofs of the results are essentially based on a new maximal inequality generalizing the Doob's maximal inequality for martingales and dyadic induction. Applications to kernel estimators are also provided.

Another direction of research is the study of Markov chains via martingale approximation. In papers 2, 9 and 11 we study the important problem of limit theorem started at a point for various classes of stochastic processes. This problem is motivated by the study of infinite systems of particles, random walks or processes in random media. In this context, the almost sure validity of the central limit theorem refers to as "quenched" media as opposed to the "annealed" media. To prove the limit theorems in paper 2, we estimate the rest of the approximation of a stationary process by a martingale in terms of the projections of partial sums. The conditions are well suited for a variety of examples; they are easy to verify, for instance, for linear processes and functions of Bernoulli shifts. Paper 9 requires a different approach since the class treated here does not accept directly a martingale approximation. The variables are first divided in large blocks, which are further decomposed in a martingale and a rest. The results are used to study the strong mixing processes as well as maps that recently came to the attention of specialists in dynamical systems. Paper 11 is a survey paper on the quenched invariance principles, summarizing the recent progress in this interesting type of limit theorems.

In paper 5 we address the problem of central limit theorem for families of Markov chains, and we made progress in a problem open for more than 50 years. We show that the coefficient of degeneracy introduced by Dobrushin can be replaced by a weaker coefficient, enlarging in this way the class of family of Markov processes having this remarkable behavior.

Dependence coefficients have been widely studied for Markov processes defined by a set of transition probabilities and an initial distribution. Paper 6 clarifies some aspects of the theory of dependence structure of Markov chains generated by copulas that are useful in time series econometrics and other applied fields.

In paper 8 we study the functional central limit theorem for stationary Markov chains with self-adjoint operator and general state space. We investigate the case when the variance of the partial sum is not asymptotically linear in n, and establish that conditional convergence in distribution of partial sums implies functional CLT. The main tools are maximal inequalities that are further exploited to derive conditions for tightness and convergence to the Brownian motion.

Paper 10 deals with the notion of stability of central limit theorem under formation of linear processes of normal or reversible Markov chains. It is pointed out that, in the case of reversible Markov chains, the absolute sumability of the covariances is the key to this type of behavior. The condition is easy to verify and so the theorem is easily applicable to time series that occur in financial applications.

The results in paper 12 sheds light on the estimation of the spectral density of a stationary process. We point out that this important quantity is the almost sure limit of the periodogram, properly normalized. The conditions imposed to the stationary process are very mild, involving logarithmic rate only of the projections of the variables on the past sigma field.

At this moment I have in progress a paper of the behavior of the variance of partial sums of functions of a stationary normal or reversible Markov chains. We obtained an interesting relation between the behavior of the spectral density induced by the Markov operator and the function and the variance, leading to a complete characterization.

(F) **Broader impact.**

The results established during the report period are expected to enrich the knowledge on the dependent sequences of random variables and on stochastic processes. I expect that these results are going to be well received and used by other mathematicians working in probability theory and related fields (ergodic theory, dynamical systems, Fourier analysis) or in applied fields such as statistics for stochastic processes with application to finance. The results on Rosenthal inequality have a vast sphere of applications since they are a main tool in analyzing empirical processes, which are fundamental for statistical applications. Self-normalizers for linear processes are very useful for statistical applications. The linear processes have a vast applicability to financial time series. The results on the Markov chains will find applications in the analysis of Monte Carlo algorithms and also in infinite particle systems. The exact asymptotics are main tools in finance and risk theory. The estimation of the periodogram plays a crucial role in the statistics of stationary processes.

At the same time these results are impacting the graduate education in my University. I am Ph.D. adviser at this moment of two graduate students. A student, Mary Lee Gore, was supported during the last year summer by this grant. We met regularly several times a week and worked on Monte Carlo algorithms.

My seminar talks are always based on my recent research as well as works in progress, contributing to the education of many graduate students.

During the reported period I served as an associate editor for Journal of Mathematical Analysis and Applications. The expertise gained from my research supported by this grant helped me perform these editorial activities. I also referred papers for Annals of Probability, Annals of Statistics, Bernoulli, Statistics and Probability Letters, Journal of Applied Probability and several other journals.

The results of my research supported by this grant were presented in international meetings and lectures.