

GRIGORY FEDYUKOVICH	
Current Position	Postdoctoral Research Associate in the Computer Science Department at Princeton University
Research interests	<p>Automated Program Verification:</p> <ul style="list-style-type: none"> • Synthesis of Proofs for Program Verification: Inductive Invariants for Safety, Ranking Functions for Termination, Existential Recurrence Sets for Non-Termination; • Solving Constrained Horn Clauses Using Syntax, Data, and Frequency Distributions; • Verification of Security Properties such as Non-Interference <p>Regression/Incremental Verification:</p> <ul style="list-style-type: none"> • Program Equivalence and Program Simulation; • Function Summarization based on Craig Interpolation <p>Program Synthesis:</p> <ul style="list-style-type: none"> • Functional (Skolem) Synthesis via Lazy Quantifier Elimination; • Enumerative Synthesis for Automatic Parallelization of Loops; • Synthesis of Secure Programs via Eliminating Timing Side-Channel Leaks
Email / Web	grigoryf@cs.princeton.edu http://www.cs.princeton.edu/~grigoryf

AFFILIATION HISTORY	
Oct 2017 - ...	<p>PostDoc: Computer Science Department at Princeton University;</p> <p>Supervised by: Prof. Aarti Gupta;</p> <p>Projects: Syntax-guided Techniques in Automated Formal Verification, Verification and Synthesis for Security</p>
Jan 2016 - Oct 2017	<p>PostDoc: Paul G. Allen School of Computer Science & Engineering at University of Washington (UW), Seattle, USA;</p> <p>Supervised by: Prof. Rastislav Bodík;</p> <p>Projects: Automatic Parallelization of Single Pass Array-handling Programs; Horn-based Verification of Functional Programs, Probabilistic SyGuS-based Invariant Synthesis</p>
Oct 2010 - Dec 2015	<p>PhD: Faculty of Informatics, Università della Svizzera italiana (USI), Lugano, Switzerland;</p> <p>Supervised by: Prof. Natasha Sharygina;</p> <p>Thesis: Automated Incremental Software Verification</p>
Apr - Oct 2010	<p>Internship: School of Computing, National University of Singapore, Singapore;</p> <p>Project: Verification of Quantified Properties over Lists in Coq</p>
Jun 2009 - March 2010	<p>Internship: Logic and Semantics group at Tallinn Institute of Cybernetics, Estonia;</p> <p>Project: A Coq Formalization of an Analysis and Optimization of While</p>

2007 - 2009	Software Engineer (Java EE): Reksoft, Saint Petersburg, Russia
2003 - 2008	Specialist Degree (Diplom): Department of Computer Science, Faculty of Mathematics and Mechanics, Saint Petersburg State University, Russia

COLLABORATION	
2018 - ...	<p>Topic: Solving Constrained Horn Clauses Using Syntax and Data</p> <p>Collaboration with: Sumanth Prabhu, Kumar Madhukar, TCS Research, Pune, India</p> <p>Publication: FMCAD 2018</p> <p>Tool Development: FreqHorn</p>
2015 - ...	<p>Topic: Synthesis from Skolemized Proofs of Realizability</p> <p>Collaboration with: Dr. Michael W. Whalen, University of Minnesota, USA</p> <p>Publication: TACAS 2018</p> <p>Tool Development: AE-VAL, JSyn</p>
2016 - ...	<p>Topic: SMT-based Incremental Bounded Model Checking</p> <p>Collaboration with: Dr. Hana Chockler, King's College, London, UK and Prof. Natasha Sharygina, USI, Switzerland</p> <p>Publications: TACAS 2017, SAT 2017, LPAR 2018</p> <p>Tool Development: HiFrog</p>
2012 - 2016	<p>Topic: Horn-based Incremental Model Checking</p> <p>Collaboration with: Prof. Arie Gurfinkel, University of Waterloo, Canada</p> <p>Publications: NFM 2014, LPAR 2015, CAV 2016</p> <p>Tool Development: Niagara</p>
2014 - 2015	<p>Topic: Partial Interpolation Framework</p> <p>Collaboration with: Prof. Jan Kofroň, Charles University, Czech Republic</p> <p>Publication: FASE 2016</p> <p>Tool Development: eVolCheck, PVAIR</p>
2010 - 2013	<p>EU project PINCETTE: number 257647, supported by European Community under the call FP7-ICT-2009-5;</p> <p>Topic: Validating Changes and Upgrades in Networked Software;</p> <p>Collaboration with: University of Oxford, IBM Israel, University of Milano Bicocca, VTT Finland, Israel Aerospace Industries Ltd., ABB Schweiz, and ABB Germany</p> <p>Publications: FMCAD 2012, TACAS 2013, LPAR 2013, ISSTA 2014</p> <p>Tool Development: eVolCheck, FunFrog</p>

GRANTS AND FELLOWSHIPS	
2018	University of Tokyo - Princeton Strategic Partnership Grant , 10 000 USD to support a new research collaboration that will facilitate the flow of scholars and graduate students between institutions
2016	Postdoc Award , University of Washington, 23 000 USD for a side-project on Horn-based Symbolic Model Checking (salaries for interns, conference travel, equipment)
2015	Early Postdoc.Mobility Fellowship , Swiss National Science Foundation, ~100 000 USD for 18 months in University of Washington (salaries for myself, medical insurance, equipment, conference travel)

SERVICE	
2019 (TBA)	<p>Program Chair: The 6th Workshop on Horn Clauses for Verification and Synthesis (HCVS 2019), Student Forum at the International Conference on Formal Methods in Computer-Aided Design (FMCAD 2019)</p> <p>Program Committee Member: International Conference on Computer Aided Verification (CAV 2019), Seventh International Workshop on Verification and Program Transformation (VPT 2019)</p> <p>Organization Committee Member: 2nd International Competition on Satisfiability of Constrained Horn Clauses (CHC-COMP 2019)</p>
2018	<p>Program Chair: Workshop on Verification and Synthesis for Software Evolution (VSSE 2018)</p> <p>Program Committee Member: The 16th International Symposium on Automated Technology for Verification and Analysis (ATVA 2018), ACM Transactions on Programming Languages and Systems (TOPLAS), ACM Transactions on Software Engineering and Methodology (TOSEM)</p> <p>Artifact Evaluation Committee Member: International Conference on Computer Aided Verification (CAV 2018)</p> <p>Organization Committee Member: 1st International Competition on Satisfiability of Constrained Horn Clauses (CHC-COMP 2018)</p> <p>Sub-reviewer: International Conference on Formal Methods in Computer-Aided Design (FMCAD 2018), 25th International Symposium on Model Checking of Software (SPIN 2018), International Conference on Computer Aided Verification (CAV 2018)</p>
2017	<p>Local Organization Chair: The 17th International Conference on Runtime Verification (RV 2017)</p> <p>Program Committee Member: The 17th International Conference on Runtime Verification (RV 2017), the 4th Workshop on Horn Clauses for Verification and Synthesis (HCVS 2017)</p> <p>Sub-reviewer: International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS 2018), The 13th Haifa Verification Conference (HVC 2017), International Conference on Formal Methods in Computer-Aided Design (FMCAD 2017), the 24th Static Analysis Symposium (SAS 2017), International Conference on Software Engineering and Formal Methods (SEFM 2017), International Conference on Computer Aided Verification (CAV 2017)</p>

2016	<p>Program Chair: Workshop on Verification and Synthesis for Software Evolution (VSSE 2016)</p> <p>Program Committee Member: International Journal on Software Tools for Technology Transfer (STTT, Selected Papers at TACAS 2016), Journal of Automated Reasoning (JAR, Selected Papers at VSTTE 2016)</p> <p>Sub-reviewer: International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS 2017), International Symposium on Formal Methods (FM 2016), International Conference on Formal Methods in Computer-Aided Design (FMCAD 2016), Conference on Verified Software: Theories, Tools, and Experiments (VSTTE 2016), International Conference on Computer Aided Verification (CAV 2016), 3rd Workshop on Horn Clauses for Verification and Synthesis (HCVS 2016)</p>
2015	<p>Sub-reviewer: International Conference on Formal Methods in Computer-Aided Design (FMCAD 2015), Journal of Automated Reasoning (JAR, Special Issue on Interpolation Techniques for Program Verification and Synthesis), International Conference on Computer Aided Verification (CAV 2015), International Symposium on Formal Methods (FM 2015), NASA Formal Methods Symposium (NFM 2015)</p>
2014	<p>Sub-reviewer: International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS 2015), International Conference on Formal Methods in Computer-Aided Design (FMCAD 2014), Ershov Informatics Conference (PSI 2014), International Conference on Computer Aided Verification (CAV 2014)</p> <p>Organization Committee Member: Workshop on Validation Strategies for Software Evolution (VSSE 2014)</p>
2013	<p>Sub-reviewer: International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS 2014), International Conference on Formal Methods in Computer-Aided Design (FMCAD 2013), Workshop on Validation Strategies for Software Evolution (VSSE 2013)</p> <p>Organization Committee Member: International Conference on Computer Aided Verification (CAV 2013)</p>
2012	<p>Sub-reviewer: International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS 2013), International Conference on Formal Methods in Computer-Aided Design (FMCAD 2012), Conference on Design, Automation and Test in Europe (DATE 2012), International Symposium on Games, Automata, Logics and Formal Verification (GandALF 2012), Working Conference on Verified Software: Theories, Tools, and Experiments (VSTTE 2012), International Conference on Computer Aided Verification (CAV 2012)</p>
2011	<p>Sub-reviewer: International Conference on Formal Methods in Computer-Aided Design (FMCAD 2011), International Conference on Formal Methods and Models for System Design (MEMOCODE 2011)</p>
2010	<p>Sub-reviewer: International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS 2011)</p> <p>Organization Committee Member: International Conference on Formal Methods in Computer-Aided Design (FMCAD 2010), Alpine Verification Meeting (AVM 2010)</p>

SOFTWARE	
2017 - ...	FreqHorn / FreqTerm , Probabilistic SyGuS-based Constrained-Horn-Clause solver and a termination / non-termination prover

2014 - ...	AE-VAL , Functional synthesizer for linear arithmetic (via lazy quantifier elimination and extracting Skolem functions)
2016 - 2017	Rosette/Unbound , Constrained-Horn-Clause-based Invariant Synthesizer for functional programs in Racket
2013 - 2016	Niagara , Constrained-Horn-Clause-based incremental model checker for C
2010 - ...	HiFrog / FunFrog / eVolCheck , incremental SAT/SMT-based bounded model checker for C with function summarization, automated detection of recursion depth, checking assertion dependencies, support for flexible interpolation, and upgrade checking capabilities

JOURNAL PUBLICATIONS AND BOOK CHAPTERS

2017	Grigory Fedyukovich, Ondrej Sery, Natasha Sharygina: Flexible Framework for Incremental Upgrade Checking . STTT, 19(5): 517-534, http://dx.doi.org/10.1007/s10009-015-0405-y
2015	Hana Chockler, Daniel Kroening, Leonardo Mariani, Natasha Sharygina (editors) Validation of Evolving Software . (4 chapters) http://dx.doi.org/10.1007/978-3-319-10623-6

PEER REVIEWED CONFERENCE PUBLICATIONS

2018	Sepideh Asadi, Martin Blicha, Grigory Fedyukovich, Antti Hyvärinen, Karine Even-Mendoza, Natasha Sharygina and Hana Chockler: Function Summarization Modulo Theories , LPAR: 56-75
2018	Grigory Fedyukovich, Sumanth Prabhu, Kumar Madhukar, Aarti Gupta: Solving Constrained Horn Clauses Using Syntax and Data , FMCAD, to appear
2018	Grigory Fedyukovich, Yueling Zhang, Aarti Gupta: Syntax-Guided Termination Analysis . CAV (1) 2018: 124-143
2018	Lauren Pick, Grigory Fedyukovich, Aarti Gupta: Exploiting Synchrony and Symmetry in Relational Verification . CAV (1) 2018: 164-182
2018	Andreas Katis, Grigory Fedyukovich, Huajun Guo, Andrew Gacek, John Backes, Arie Gurfinkel, Michael Whalen: Validity-Guided Synthesis of Reactive Systems from Assume-Guarantee Contracts . TACAS (2): 176-193 invited for a Special Issue of Journal of Automated Reasoning (JAR)
2018	Grigory Fedyukovich, Rastislav Bodík: Accelerating Syntax-Guided Invariant Synthesis . TACAS (1): 251-269
2017	Grigory Fedyukovich, Samuel Kaufman, Rastislav Bodík: Sampling Invariants from Frequency Distributions . FMCAD: 100-107, invited for a Special Issue of the Formal Methods in Systems Design (FMSD) journal

2017	Antti Eero Johannes Hyvärinen, Sepideh Asadi, Karine Even-Mendoza, Grigory Fedyukovich, Hana Chockler, Natasha Sharygina: Theory Refinement for Program Verification. SAT: 347-363
2017	Grigory Fedyukovich, Maaz Bin Safeer Ahmad, Rastislav Bodík: Gradual Synthesis for Static Parallelization of Single-Pass Array-Processing Programs. PLDI: 572-585
2017	Dmitry Mordvinov, Grigory Fedyukovich: Synchronizing Constrained Horn Clauses. LPAR: 338-355
2017	Leonardo Alt, Sepideh Asadi, Hana Chockler, Karine Even-Mendoza, Grigory Fedyukovich, Antti Eero Johannes Hyvärinen, Natasha Sharygina: HiFrog: SMT-based Function Summarization for Software Verification. TACAS (2): 207-213
2016	Grigory Fedyukovich, Rastislav Bodík: Approaching Symbolic Parallelization by Synthesis of Recurrence Decompositions. SYNT@CAV: 55-66
2016	Grigory Fedyukovich, Arie Gurfinkel, Natasha Sharygina: Property Directed Equivalence via Abstract Simulation. CAV (2): 433-453
2016	Pavel Jancík, Leonardo Alt, Grigory Fedyukovich, Antti Eero Johannes Hyvärinen, Jan Kofroň, Natasha Sharygina: PVAIR: Partial Variable Assignment Interpolator. FASE: 419-434
2015	Grigory Fedyukovich, Arie Gurfinkel, Natasha Sharygina: Automated Discovery of Simulation Between Programs. LPAR: 606-621
2015	Leonardo Alt, Grigory Fedyukovich, Antti Eero Johannes Hyvärinen, Natasha Sharygina: A Proof-Sensitive Approach for Small Propositional Interpolants. VSTTE: 1-18
2015	Grigory Fedyukovich, Andrea Callia D'iddio, Antti Eero Johannes Hyvärinen, Natasha Sharygina: Symbolic Detection of Assertion Dependencies for Bounded Model Checking. FASE: 186-201
2014	Grigory Fedyukovich, Natasha Sharygina: Towards Completeness in Bounded Model Checking Through Automatic Recursion Depth Detection. SBMF: 96-112
2014	Fabrizio Pastore, Leonardo Mariani, Antti Eero Johannes Hyvärinen, Grigory Fedyukovich, Natasha Sharygina, Stephan Sehestedt, Ali Muhammad: Verification-aided Regression Testing. ISSTA: 37-48
2014	Grigory Fedyukovich, Arie Gurfinkel, Natasha Sharygina: Incremental Verification of Compiler Optimizations. NFM: 300-306
2013	Simone Fulvio Rollini, Leonardo Alt, Grigory Fedyukovich, Antti Eero Johannes Hyvärinen, Natasha Sharygina: PeRIPLO: A Framework for Producing Effective Interpolants in SAT-based Software Verification. LPAR: 683-693

2013	Grigory Fedyukovich, Ondrej Sery, Natasha Sharygina: eVolCheck: Incremental Upgrade Checker for C. TACAS: 292-307 best student contribution award, invited for a Special Issue of Software Tools for Technology Transfer (STTT) journal
2012	Ondrej Sery, Grigory Fedyukovich, Natasha Sharygina: Incremental Upgrade Checking by Means of Interpolation-based Function Summaries. FMCAD: 114-121
2012	Ondrej Sery, Grigory Fedyukovich, Natasha Sharygina: FunFrog: Bounded Model Checking with Interpolation-based Function Summarization. ATVA: 203-207
2011	Ondrej Sery, Grigory Fedyukovich, Natasha Sharygina: Interpolation-Based Function Summaries in Bounded Model Checking. HVC: 160-175

TALKS AND SEMINARS

2019 (TBA)	Invited seminar Synthesizing Proofs for Program Verification. USI, Switzerland. Host: Prof. Natasha Sharygina
2018 (TBA)	Invited seminar Synthesizing Proofs for Program Verification. University of Waterloo, Canada. Host: Prof. Arie Gurfinkel
2018	Invited seminar Synthesizing Proofs for Program Verification. University of Pennsylvania, USA. Host: Prof. Rajeev Alur
2018	Conference talk Solving Constrained Horn Clauses Using Syntax and Data. FMCAD, Austin, USA
2018	Invited seminar Synthesizing Proofs for Program Verification. University of Texas at Austin, USA. Host: Prof. Isil Dillig
2018	Invited seminar Synthesizing Proofs for Program Verification. Academia Sinica, Taipei, Taiwan. Host: Prof. Yu-Fang Chen
2018	Invited seminar Synthesizing Proofs for Program Verification. University of Maryland at College Park, USA. Host: Prof. David Van Horn
2018	Invited seminar Syntax-Guided Termination Analysis. TCS Research, Pune, India. Hosts: Sumanth Prabhu, Kumar Madhukar
2018	Conference talk Syntax-Guided Termination Analysis. CAV, Oxford, UK
2018	Invited seminar Sampling Invariants from Frequency Distributions, Saint Petersburg State University, Russia. Host: Dmitry Mordvinov
2018	Invited seminar Sampling Invariants from Frequency Distributions, New York University, USA. Host: Prof. Thomas Wies

2018	Invited seminar Sampling Invariants from Frequency Distributions , Yale University, USA. Host: Prof. Ruzica Piskac
2018	Conference talk Accelerating Syntax-Guided Invariant Synthesis . TACAS, Thessaloniki, Greece
2018	Invited talk Property Directed Equivalence via Abstract Simulation , Dagstuhl Seminar 18151 on Program Equivalence, Dagstuhl, Germany
2017	Invited seminar Synchronizing Constrained Horn Clauses , USI, Switzerland. Host: Prof. Natasha Sharygina
2017	Invited seminar Sampling Invariants from Frequency Distributions , Charles University, Prague, Czech Republic. Host: Prof. Jan Kofroň
2017	Conference talk Sampling Invariants from Frequency Distributions , FMCAD, Vienna, Austria
2017	Invited seminar Synchronizing Constrained Horn Clauses , Macquarie University, Sydney, Australia. Host: Prof. Franck Cassez
2017	Invited seminar Synchronizing Constrained Horn Clauses , SRI International, Menlo Park, USA. Host: Dr. Jorge Navas
2017	Invited seminar Synchronizing Constrained Horn Clauses , KTH, Stockholm, Sweden. Host: Prof. Philipp Haller
2017	Invited seminar Synchronizing Constrained Horn Clauses , IMDEA Software Institute, Madrid, Spain. Host: Dr. Pedro López García
2017	Conference talk Gradual Synthesis for Static Parallelization of Single-Pass Array-Processing Programs , PLDI, Barcelona, Spain
2017	Invited seminar Synchronizing Constrained Horn Clauses , University of California San Diego, USA. Host: Prof. Ranjit Jhala
2017	Conference talk Synchronizing Constrained Horn Clauses , LPAR, Maun, Botswana
2017	Invited seminar Automated Incremental Software Verification , Tsinghua University, Beijing, China. Host: Prof. Fei He
2017	Invited seminar SMT-based Function Summarization for Incremental Software Verification , University of Massachusetts Lowell, USA. Host: Prof. Jay McCarthy
2017	Invited seminar SMT-based Function Summarization for Incremental Software Verification , USI, Switzerland. Host: Prof. Natasha Sharygina

2016	Invited seminar Automated Incremental Software Verification , Seoul National University, Seoul, Korea. Host: Prof. Chung-Kil Hur
2016	Invited seminar Automated Incremental Software Verification , Hong Kong University of Science and Technology, Hong Kong. Host: Prof. S.C. Cheung
2016	Invited seminar Witnessing Existential Quantifiers with AE-VAL , USI, Switzerland. Host: Prof. Natasha Sharygina
2016	Workshop talk Gradual Synthesis for Static Parallelization . PLSE Retreat, Leavenworth, USA
2016	Workshop talk What's Reusable in Program Analysis . TAPAS, Edinburgh, UK
2016	Conference talk Property Directed Equivalence via Abstract Simulation , CAV, Toronto, Canada
2016	Workshop talk Approaching Symbolic Parallelization by Synthesis of Recurrence Decompositions . SYNT, Toronto, Canada
2016	Invited seminar Property Directed Equivalence via Abstract Simulation , USI, Switzerland. Host: Prof. Natasha Sharygina
2016	Invited seminar Automated Incremental Software Verification , UW, Seattle, USA
2015	Conference talk Automated Discovery of Simulation Between Programs , LPAR, Suva, Fiji
2015	Workshop talk AE-VAL: Horn clause-based Skolemizer for Forall-Exists-formulas , HCVS, San Francisco, USA
2015	Workshop talk Incremental Proof-Based Verification of Compiler Optimizations , AVM, Attersee, Austria
2015	Conference talk Symbolic Detection of Assertion Dependencies for Bounded Model Checking , FASE, London, UK
2014	Conference talk Towards Completeness in Bounded Model Checking Through Automatic Recursion Depth Detection , SBMF, Maceio, Brazil
2014	Conference talk Incremental Verification of Compiler Optimizations , NASA Formal Methods, Houston, USA
2014	Invited talk Producing Effective Interpolants for SAT-based Incremental Verification and Upgrade Checking , VSSE, Grenoble, France

2013	Conference talk PeRIPLO: A Framework for Producing Effective Interpolants in SAT-based Software Verification Hardware Verification , LPAR, Stellenbosch, South Africa
2013	Workshop talk Incremental Upgrade Checking by means of Interpolation-based Function Summaries , VPT, Saint Petersburg, Russia
2013	Invited seminar Interpolation-based Model Checking for Efficient Incremental Analysis of Software at SEI/CMU, Pittsburgh, USA. Host: Dr. Arie Gurfinkel
2013	Conference talk eVolCheck: Incremental Upgrade Checker for C , TACAS, Rome, Italy
2013	Invited talk Incremental Model Checking for Upgrade Checks , VSSE, Rome, Italy
2013	Invited talk and demo Upgrade Checking in eVolCheck , ABB Schweiz, Baden, Switzerland. Host: Dr. Manuel Oriol
2012	Conference talk FunFrog: Bounded Model Checking with Interpolation-based Function Summarization , ATVA, Trivandrum, India
2012	Workshop talk Interpolation-based Function Summaries in Bounded Model Checking , LfSA, Berkeley, USA
2012	Invited talk Software Model Checking , IMT, Irkutsk, Russia
2012	Workshop talk Bounded Model Checking with Interpolation-based Function Summarization , AVM, Passau, Germany
2011	Poster session Function Summaries in Software Upgrade Checking , HVC, Haifa, Israel
2011	Tutorials FunFrog: Bounded Model Checking with Interpolation-based Function Summarization , VTT and Nokia, Tampere, Finland. Host: Dr. Ali Muhammad
2010	Seminar Of the Verification of List Properties , NUS, Singapore
2010	Workshop talk A Coq Formalization of an Analysis and Optimization of While , Estonian Computer Science Theory Days, Andu, Estonia

TEACHING

2018	Course instructor of Independent Work Seminar IW09 on Programs Generating Programs , Princeton University, USA
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2018	External Review Committee of Bachelor Theses (by Lidiia Chernigovskaia and Aleksandr Misonizhnik), Saint Petersburg State University, Russia
2017	Invited lecture Invariant Generation at the Automated Reasoning about Software course, Princeton University, USA
2017	Student projects on Equivalence Checking, Incremental BMC, and Invariant Generation at the Automated Reasoning about Software course, Princeton University, USA
2016	Invited lecture SMT solving in Software Verification at the Logic course, USI, Switzerland
2015	Teaching assistantship at the Computer Aided Verification course, USI, Switzerland
2014	Lab Spin Model Checker at the Validation and Verification course, ALaRI, USI, Switzerland
2012	Teaching assistantship at the Computer Architecture course, USI, Switzerland
2012	Teaching assistantship at the Automata and Formal Languages course, USI, Switzerland
2011	Teaching assistantship at the Linear Algebra course, USI, Switzerland