Abhik Roychoudhury

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Professor, National University of Singapore (NUS)

Lead Principal Investigator, Singapore Cyber-security Consortium

Director, National Satellite of Excellence in Trustworthy Software Systems

Brief Biography

Abhik Roychoudhury is a Professor of Computer Science at the National University of Singapore. His research focuses on software testing and analysis, software security and trust-worthy software construction. His research group has built scalable techniques for testing, debugging and repair of programs using systematic semantic analysis. The research on automatically repairing programs at a large scale contributes to the vision of self-healing software. He has been an ACM Distinguished Speaker (2013-19). He is the Director of the *National Satellite of Excellence on Trustworthy Software Systems* at Singapore (2019-23). He is currently leading the TSUNAMi center, a large five-year long targeted research effort funded by National Research Foundation in the domain of trust-worthy software. He is also the Lead Principal Investigator of the *Singapore Cyber-security Consortium*, which is a consortium of around 40 companies in the cyber-security space engaging with academia for research and collaboration. His research has been funded by various agencies and companies, including the National Research Foundation (NRF), Office of Naval Research (ONR), Singapore Ministry of Education (MoE), A*STAR, Defense Research and Technology Office (DRTech), DSO National Laboratories, Microsoft and IBM. He has been a keynote speaker at several conferences, and he has served in various capacities in the program committees and organizing committees of various conferences on software engineering, specifically serving as Program Chair of ACM International Symposium on Software Testing and Analysis (ISSTA) 2016 and General Chair of ACM SIGSOFT Symposium on Foundations of Software Engineering (FSE) 2022. He has served as an Editorial Board member of IEEE Transactions on Software Engineering (TSE) during 2014-18. His former students have been placed at universities all over the world as academics (Peking University, University College London, Monash, SUTD) and have received various awards for their PhD research, including an ACM SIGSOFT Outstanding Doctoral Dissertation Award. Abhik received his Ph.D. in Computer Science from the State University of New York at Stony Brook in 2000.

Research Interests

- Program Analysis, Trustworthy Software, Software Security, Program Repair, Real-time Embedded Systems.

Education

- Ph.D. Computer Science (2000), State University of New York (SUNY) at Stony Brook (USA). *Dissertation:* Program Transformations for Verifying Parameterized Systems.
- M.S. Computer Science (1997), State University of New York (SUNY) at Stony Brook (USA).
- B.E. Computer Engineering (1995), Jadavpur University (India), GPA: 5.00/5. *Dissertation:* Efficiently Computing Vertex Arboricity of Planar Graphs.

Employment

At National University of Singapore (NUS)

- Jan 2019 onwards: Director, National Satellite of Excellence in Trustworthy Software Systems.

- July 2016 onwards: Lead PI and Acad Director, Singapore Cyber-security Consortium.
- July 2014 onwards: Professor (Tenured), School of Computing, NUS.
- July 2013 - 2016: Vice Dean of Graduate Studies (with responsibility for ∼500 graduate students), School of Computing, NUS.
- Jan 2011- June 2013: Assistant Dean of Graduate Studies, School of Computing, NUS.
- July 2007 - June 2014: Associate Professor (Tenured), School of Computing, NUS.
- January 2001 - June 2007: Assistant Professor (Tenure-track), School of Computing, NUS.

Funded Research Projects

- As Principal Investigator (PI)
  - *National Satellite of Excellence in Trustworthy Software Systems*, Lead PI and Director, $12M, 2019-23 (4 years).
  - *Self-Healing Software*, Lead PI, USD 120K, Funded by Office of Naval Research (ONR), 2016-18.
  - *Singapore Cyber-security Consortium*, Lead PI, $4.8 M, 2016-22 (6 years). The Consortium currently has ∼ 50 member companies. I was heavily involved for setting up this first industry Consortium in Computer Science at Singapore.
  - *A fully automated cloud based testing solution for mobile apps*, Innovation grant funded by SMART, PI, $250K, 2016-18 (2 years).
  - *TSUNAMi: Trustworthy Systems from UN-trusted component Amalgamations*, Lead PI, Funded by National Research Foundation (NRF), 2015 - 2020 (5 years), $6.1 M.
  - *Energy aware Programming*, PI, Funded by Ministry of Education (MoE), 2014 - 2017 (3 years), $ 466,000.
  - *CODETEST: Comprehension Detection and Testing via Symbolic Execution*, PI, Funded by DSO Labs, 2013 - 15 (2 years), $ 390,000.
  - *Scalable Timing Analysis Methods for Embedded Software*, PI, Funded by A*STAR Public Sector Funding (PSF), 2012 - 2015 (3 years), $ 590,000.
  - *Analysis and Test Generation for Evolving Software*, PI, Funded by Ministry of Education (MoE), 2011 - 2014 (3 years), $ 831,000.
  - *Symbolic Taint Analysis*, PI, Funded by Defense Research and Technology Office (DRTech) under Defence Innovative Research Program (DIRP), 2009-2012 (3 years), $ 397,290.
  - *Tools and techniques for Model based Software Debugging*, PI, Funded by Agency of Science Technology and Research (A*STAR), September 2004 - 2007 (3 years), $362,000.
  - *Correctness and Performance Issues in the CLI memory model*, PI, a small grant funded by Microsoft for one year (2005-2006), US$15,000.
- As Co-Principal Investigator (Co-PI)
  - *EASEL: Engineering Architectures and Software for the Embedded Landscape*, Co-PI, Funded by Agency of Science Technology and Research (A*STAR), 2006-09, $1.35 million.
  - *Formal Design Techniques for Reactive Embedded Systems*, Co-PI, Funded by Agency of Science Technology and Research (A*STAR), 2003 - 2006 (3 years), $429,000.

Invited Talks

- Invited talks given in my role as ACM Distinguished Speaker are *not* included the following.
- Distinguished Lecture, Max Planck Institute for Software Systems (MPI SWS), upcoming in July 2019.
- Invited Speaker, ISSTA 2019 Summer School, Upcoming in July 2019.
- Invited Speaker, Huawei Strategy and Technology Workshop, Upcoming in May 2019.
- *Symbolic Execution vs. Search for Software Vulnerability Detection and Patching*
  Invited Speaker, 8th International Conference on Security, Privacy and Cryptography Engineering (SPACE), December 2018.
- *Automated Program Repair*
  Keynote Speaker, 25th Australasian Software Engineering Conference (ASWEC), Adelaide, November 2018.
- *Symbolic Execution for Software Vulnerability Detection and Repair*
  Invited Speaker, 9th International Summer School on Information Security and Protection (ISSISP), Australian National University, Canberra, July 2018.
- *From Timing and Energy Analysis to Testing*
  Keynote Speaker, 21st IEEE International Symposium on Real-time Computing (ISORC), May 2018.
- *Software Vulnerability Detection and Repair*
  Keynote Speaker, KLEE Workshop on Symbolic Execution, Imperial College London, April 2018.
- *Trustworthy Software*
  Distinguished Lecture at Peking University China, as part of 7th International Symposium on High Confidence Software, December 2017.
- *Future of Mobile software - Performance and Energy issues*
  Keynote at 4th IEEE/ACM International Conference on Mobile Software Engineering and Systems (MobileSoft), May 2017.
- *Binary Analysis for Vulnerability Detection*
  Distinguished Lecture, University of Luxembourg, Interdisciplinary Centre for Security, Reliability and Trust (SnT), January 2017.
- *General Summary of Program Repair and Semantic Repair*
  Overview talk at Dagstuhl Seminar on Automated Program Repair, Saarbrucken, Germany, January 2017.
- *Symbolic Techniques for Software Debugging*
  Overview talk at Dagstuhl Seminar on Symbolic Execution and Constraint Solving, Saarbrucken, Germany, October 2014.
- *SEMFIX: Automated repair via Semantic Analysis*
  at Dagstuhl Seminar on Fault Prediction, Localization and Repair - Saarbrucken, Germany, February 2013. Also, given at the CREST workshop on Search based software testing and Symbolic Execution, London, January 2014.

- *How Symbolic Reasoning can help Program Debugging and Repair*
  Workshop on Future of Debugging, International Symposium on Software Testing and Analysis (ISSTA) 2013, July 2013, Lugano, Switzerland.

- *Formal techniques for debugging software regressions*
  Invited talk at International Seminar on Program Verification, Automated Debugging and Symbolic Computation (PAS) 2012, Beijing, China. Organized by Chinese Academy of Sciences.

- *Debugging as a Science, that too, for Evolving Programs*
  Keynote given at 3rd International Workshop on Harnessing Theories for Tool Support in Software (TTSS) 2009, a workshop held along with the International Colloquium on Theoretical Aspects of Computing (ICTAC) 2009, August 2009.

- *Automated Generation of Protocol Converters from Scenario-based Specifications*
  Workshop on Predictable Software Component Assembly, Sponsored by CoLogNet (the European Network for Excellence in Computational Logic), May 2004, Venue: Manchester, UK.

- *Program Transformations for Automated Verification*
  Invited tutorial at *International Conference on Logic Programming (ICLP)*, as part of Federated Logic Conferences (FLoC), August 1 2002, Copenhagen (Denmark).

Key Research Contributions

Automated Program Repair Automated program repair is a promising new technology, which seeks to reduce manual effort from the programmer. Such a technology can also be used for automated repair of security vulnerabilities, which often remain un-fixed even after being detected and reported. We envision program repair as a specification inference process, rather than a search problem. We show that selective use of symbolic execution and concrete execution can infer specifications about how a given program should be rectified. Such specifications or constraints can again be solved either via enumerative search or via program synthesis. We investigate a variety of semantic signatures that can be efficiently inferred, develop new powerful synthesis technology based on second order logic, and conduct extensive experimentation over various large code-bases. Automated repair, and use of systematic analysis for this purpose, has been gaining practical traction. As an example, one could look into the latest tools from Facebook on automated repair. Overall, semantic program repair takes one key step towards building trustworthy self-healing software. Apart from its promise in fixing vulnerabilities, we have also studied the use of program repair in education, specifically for grading and giving feedback in programming assignments.

- **[ICSE'13]** "SemFix: Program Repair via Semantic Analysis", Hoang D.T. Nguyen, Dawei Qi, Abhik Roychoudhury, Satish Chandra, *IEEE/ACM International Conference on Software Engineering (ICSE) 2013.*

- **[ICSE'16]** "Angelix: Scalable Multiline Program Patch Synthesis via Symbolic Analysis" Sergey Mechtaev, Jooyong Yi, Abhik Roychoudhury, *ACM/IEEE International Conference on Software Engineering (ICSE) 2016.*

- **[CACM'19]** "Automated Program Repair", Claire Le Goues, Michael Pradel, Abhik Roychoudhury, Review article in Communications of the ACM, To appear.

Symbolic Execution and Fuzz Testing Fuzz testing is a popular method for security vulnerability detection in programs, with widespread and daily usage in industry. In terms of industry usage, the commonly used techniques involve black-box fuzzing which employs random mutations on the input, and grey-box fuzzing which employs compile time instrumentation to mutate inputs via a biased-random search. On the other hand, white-box fuzzing or symbolic execution, widely studied in academia, relies on program analysis and constraint solving for systematic testing. In our work, we have brought in ideas and technologies from symbolic execution for systematic fuzz testing. Conventionally symbolic execution based on testing attempts to either enhance path coverage, or perform a directed search for reaching specific program locations. We have shown how such ideas from symbolic execution can be transported to grey-box fuzz testing without incurring the overheads of constraint solving. The resultant technologies have been adopted in the widely used distribution of American Fuzzy Lop (AFL), the most widely used security-testing tool. The resultant technologies were used in DARPA Cyber Grand Challenge 2016 for faster vulnerability detection.

- **[CCS'16]** "Coverage-based Greybox Fuzzing as Markov Chain" Marcel Böhme, Van Thuan Pham, Abhik Roychoudhury *23rd ACM Conference on Computer and Communications Security (CCS) 2016.*
- **[NDSS'19]** "Neuro-Symbolic Execution: Augmenting Symbolic Execution with Neural Constraints" Shiqi Shen, Shweta Shinde, Soundarya Ramesh, Prateek Saxena, Abhik Roychoudhury *26th Network and Distributed System Security Symposium (NDSS) 2019.*

Testing and Analysis of Non-functional program properties My research group has been instrumental in building the Chronos tool, which is used in research groups and organizations worldwide to estimate the Worst-case Execution Time (WCET) of sequential programs. Building on this line of work, we have also recently studied test generation to stress non-functional properties.

- **[SCP-Journal'07]** "Chronos: A Timing Analyzer for Embedded Software", Xianfeng Li, Yun Liang, Tulika Mitra and Abhik Roychoudhury, *Science of Computer Programming*, Vol 69, December 2007.
- **[TECS'14]** A Unified WCET Analysis Framework for Multi-core Platforms Sudipta Chattopadhyay, Lee Kee Chong, Abhik Roychoudhury, Timon Kelter, Peter Marwedel, Heiko Falk *ACM Transactions on Embedded Computing Systems (TECS), 13(4s), July 2014.*
- **[FSE'14]** "Detecting Energy Bugs and Hotspots in Mobile Apps", Abhijeet Banerjee, Lee Kee Chong, Sudipta Chattopadhyay, Abhik Roychoudhury *ACM SIGSOFT International Symposium on the Foundations of Software Engineering (FSE), 2014.*

Awards and Honors

- ACM Distinguished Speaker, 2013-19.
- Distinguished Reviewer Award, ASE 2018.
- ACM SIGSOFT Distinguished Paper Award (from SIGSOFT FSE 2009).
- IBM Faculty Award, 2009.
- Tan Kah Kee Young Inventor's Award, Silver Award in Open Section, for building the Java program debugging and comprehension tool JSlice, 2008.
- Best paper award nomination from

- IEEE Real-time Systems Symposium (RTSS) 2011, 2013.
- IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS) 2011.
- ACM Design Automation Conference (DAC) 2009.
- Intl. Conf. on Hardware Software Codesign and System Synthesis (CODES-ISSS) 2008.
- 19th Euromicro Conference on Real-time Systems (ECRTS) 2007.

- Award and Medal for 1st rank in Engineering Faculty, Jadavpur University (India) in freshman and sophomore years (1991-1993), and 2nd rank in Engineering Faculty, Jadavpur University (India) in junior and senior years (1993-1995).
- National Scholarship and Award for ranking 8th among all candidates in Higher Secondary Education (equivalent of A levels) in the state of West Bengal, India, 1991.
- Ranked 2nd among all candidates in the West Bengal Joint Entrance Examination for admission to Engineering colleges/institutes in the state of West Bengal, India, 1991.

Supervision and Mentoring

- *Post-doctoral Fellows*
  - Dr. Marcel Böhme, Ph.D. NUS, post-doc from 2015-17,
    moved to Monash University as Lecturer, currently ARC DECRA fellow.
  - Dr. Jooyong Yi, Ph.D. Aarhus University, Denmark, post-doc 2012-2016,
    moved to UNIST (Korea) as Assistant Professor.
  - Dr. Konstantin Rubinov, Ph.D. University of Lugano, Switzerland, post-doc 2013-2015.
  - Dr. Clement Ballabriga, Ph.D. University of Toulouse, France, post-doc 2012-2014,
    Assistant Professor in University of Lille, France since September 2014.
  - Dr. Bruno C.d.S. Oliveira, Ph.D Oxford University, UK, post-doc 2012 - 13,
    Moved as Assistant Professor to Hong Kong University (HKU).
  - Dr. Ansuman Banerjee, Ph.D. IIT Kharagpur India (07), post-doc 2010
    Currently Associate Professor at Indian Statistical Institute.
  - Dr. Sun Meng, Ph.D. Peking University China (05), post-doc 2005-06
    Currently Professor at Peking University.
- *PhD thesis supervised*
  - Sergey Mechtaev, 2018, Sole Supervision
    Moved to University College London (UCL) as Lecturer
    Thesis: Semantic Program Repair
    Recipient of 2019 ACM SIGSOFT Outstanding Doctoral Dissertation Award.
  - Shin Hwei Tan, 2018, Sole Supervision
    Moved to Southern University of Science and Technology (SUSTech) as Asst. Professor
    Thesis: Design of repair operators for automated program repair
    Received Dean's Graduate Award during PhD studies.
  - Van-Thuan Pham, 2017, Sole Supervision
    Thesis: Enhancing directed search in black-box, grey-box and white-box fuzz testing
  - Abhijeet Banerjee, 2016, Sole Supervision
    Thesis: Static analysis driven testing of performance and energy consumption properties
    Received Dean's Graduate Award during PhD studies.

- Marcel Böhme, (2014), Sole Supervision
  Moved to Monash University as Lecturer, awarded ARC DECRA Fellowship
  Thesis: Automated regression testing and verification of complex code changes.
- Dawei Qi, (2013), Joint supervision with Zhenkai Liang
  Moved to WorldQuant Singapore,
  Thesis: Semantic Analyses to detect and localize software regression errors
  Recipient of NUS Presidential Graduate Fellowship, **Best PhD thesis** award 2013.
- Sudipta Chattopadhyay, (2013), Sole Supervision
  Assistant Professor at Singapore University of Technology and Design (SUTD)
  Thesis: Timing analysis of embedded software running on multi-cores
  Recipient of NUS Presidential Graduate Fellowship.
- Sandeep Kumar, (2012), Joint supervision with Siau Cheng Khoo,
  Currently at Google Mountain View
  Thesis: Dynamic analysis based Multi-view Specification Mining.
- Lei Ju, Ph.D.(2010), Joint supervision with Samarjit Chakraborty
  Moved to Shandong University (China) as Associate Professor
  Thesis: Model-driven timing analysis of embedded software.
- Ankit Goel, Ph.D., Sole supervision,
  Thesis: Parameterized Validation of MSC-based System Models.
- Vivy Suhendra, Ph.D. (graduated 2009), Co-supervised with Tulika Mitra,
  Currently Executive Director of Singapore Cyber-security Consortium
  Thesis: Memory Optimizations for Developing Predictable Embedded Software
  Awarded Microsoft Research Asia Fellowship during PhD studies.
- Tao Wang, Ph.D. (graduated Feb 2008), Sole Supervision,
  Moved to: Morgan Stanley, Currently Vice President.
  Thesis: Bytecode level Dynamic Analysis for Software Debugging
  Best PhD thesis 2008, Microsoft Research Asia Fellowship, Presidential Graduate Fellowship.
- Xianfeng Li, Ph.D. (graduated Dec 2005), Co-supervised with Tulika Mitra,
  Moved to: Peking University (currently Professor)
  Thesis: Micro-architectural modeling for Timing Analysis of Embedded Software
  Awarded Dell Fellowship, Dean's Graduate Award during his PhD study at NUS.

- *Masters thesis supervised*
  - Chong Lee Kee, Graduated 2015,
    Integrated Timing Analysis of Application and Operating Systems Code.
  - Bach Khoa Huynh, (Graduated 2010),
    Timing analysis of data intensive programs.
  - Shanshan Liu, (Graduated 2009),
    Model checking of Parameterized Systems,
    First employment: DBS, Singapore.
  - Liang Guo, (Graduated 2008),
    Debugging Statechart Models via Model-code Traceability,
    First Employment: CreditSuisse, Singapore.
  - Tuan-Anh Tran, M.Sc. (Graduated 2005),
    Protocol Converters from Scenario-based Specifications,
    First Employment: Friar Tuck Pte Ltd (Singapore).

- Qinghua Shen, M.Sc. (Graduated 2004),
  Multi-threaded Java from Multi-processor Perspective,
  First Employment: Creative Technology Ltd (Singapore).
- Hemendra Singh Negi, M.Sc. (Graduated 2004),
  Two Concrete Problems in Worst-Case Execution Time Analysis,
  First Employment: Mentor Graphics, New Delhi (India).
- Lei Xie, M.Sc. (Graduated 2003),
  Performance Impact of Multi-threaded Java Semantics on Multiprocessor Memory Models.

- *Undergraduate student supervision:* Supervised the final year project of at least fifteen (15) final year undergraduate students at NUS School of Computing.

Teaching Experience

- Written a textbook for senior undergraduate courses, entitled "*Embedded Systems and Software Validation*". The book has been published by Elsevier (formerly Morgan Kaufmann) Systems-on-Silicon series in 2009. It has been adopted in courses at different universities spread over various countries (USA, China, Czech Republic, New Zealand, South Korea and India). The book has been highlighted in EE Times as *Editor's Top Picks* in 2012. A Chinese translation of the book has been done at the behest of Tsinghua University Press, and the Chinese version has subsequently been adopted for teaching at various Chinese universities.

- Two of my PhD students have received the *Best PhD Thesis* award from NUS School of Computing
  - Dr. Dawei Qi, Best PhD Thesis 2013, Semantic Analyses to detect and localize software regression errors
  - Dr. Tao Wang, Best PhD Thesis 2008, Post-mortem Dynamic Analysis for Software Debugging

- Several of my PhD students have been placed at academic positions including
  - Dr. Sergey Mechtaev, Lecturer, University College London.
  - Dr. Marcel Böhme, Lecturer, Monash University, ARC DECRA Fellow.
  - Dr. Sudipta Chattopadhyay, Assistant Professor, Singapore University of Technology and Design.
  - Dr. Shin Hwei Tan, Assistant Professor, Southern University of Science and Technology (SUSTech), China
  - Dr. Lei Ju, Associate Professor, Shandong University, China.
  - Dr. Xianfeng Li, Professor, Peking University, China.

- Taught following courses at NUS in both undergraduate and graduate levels.
  - CS 6210 *Art of Computer Science Research*
    Graduate course to introduce PhD students to planning of PhD studies, how to choose a topic, how to evaluate contributions of papers, writing papers and making presentations.
  - CS 4211 *Formal Methods in Software Engineering*
    In this undergraduate course, I cover formal techniques in various aspects of software engineering including requirements, design, coding and testing. Temporal logics and Live Sequence Charts are covered under requirements and formal semantics of UML diagrams

are covered under modeling. Software model checking and interactive theorem proving are covered as some of the core formal methods. Finally symbolic analysis and dependency analysis are covered in a formal fashion as the formal foundations of testing and debugging.

- CS 4239 *Software Security*
  This was a new undergraduate course proposed by me, covering software vulnerabilities and various techniques such as fuzzing to detect and prevent these vulnerabilities.
- CS 4218 *Software Testing*
  This was a new undergraduate course proposed by me. The students are exposed to techniques, tools, project work and research on testing. The students also work on a substantial hands-on project which simulates industrial realities such as personnel leaving organizations and its impact on software comprehension and testing.
- CS 6880 *Advanced Topics in Software Engineering*
  Proposed and designed this graduate advanced course with comprehensive coverage of requirements, modeling and implementation of software. The course involves paper presentation, a project on one of the cutting edge topics on Software Engineering (SaaS, Out-sourcing etc) and an examination.
- CS 5219/6214 *Automated Software Validation*
  Proposed and designed this graduate course in software validation which studies model checking, theorem proving and their combinations.
- CS 4271 *Critical Systems and their Verification*
  Designed this undergraduate course on system modeling and verification, focusing on model checking
- CS 4272 *Hardware Software Codesign*
  This undergraduate course covers Modeling, Hardware-Software Partitioning, Software Analysis, Compilation and Hardware Platforms. I made substantial changes in the course contents.
- CS 3211 *Parallel and Concurrent Programming*
  I re-designed the course with equal emphasis on concurrency concepts, multi-threaded programming in Java, and parallel programming in MPI.
- CS 2104 *Programming Language Concepts*
  This is a first course on principles of programming languages that I taught twice — in 2001-02 and 2002-03.
- CS 1102 *Data Structures and Algorithms*
  This is a first course in data structures and programming that I taught in 2000-01.

- Contributed article on education/pedagogy based on experience in teaching courses on formal verification — "Introducing Model Checking to Undergraduates" by Abhik Roychoudhury, In Formal Methods Education Workshop 2006 (co-located with Formal Methods Symposium (FM) 2006). The paper is available from
  `http://www.comp.nus.edu.sg/~abhik/pdf/fm-ed06.pdf`

Software Tools released

- *AFLFast* and *AFLGo* are extended grey-box fuzzing tools, built on top of the popular AFL fuzzer, for detecting program vulnerabilities. AFLFast has been integrated to the regular AFL distribution after significant discussion within the AFL user group. AFLFast was also used in the DARPA Cyber Grand Challenge 2016 finals by the Codejitsu team for detecting vulnerabilities quickly. A distribution of AFLFast is available from `https://github.com/mboehme/aflfast`

- *Angelix* tool for automated repair of C programs using symbolic execution, has been used for intelligent tutoring systems to teach programming to large cross-sections of students in India, in collaboration with Indian Institute of Technology (IIT) Kanpur. The tool is currently being used by 80 research groups. Such systematic analysis for automated repair, has been gaining practical traction. As an example, one could look into the latest tools from Facebook on automated repair.[1] A distribution of Angelix is available from `http://angelix.io/`

- *Jslice, a dynamic slicing tool for debugging Java programs.*
  Dynamic slicing is a popular and well-known software analysis technique. It is useful for program debugging as well as comprehension of program functionality/performance. It can also be integrated as a module in many software validation tools (such as software model checkers). Slicing can explain the reasons for unexpected variable values in a program execution, by analyzing control and data dependencies. To the best of our knowledge, prior to our work no dynamic slicing tool was available for Java programs. The Jslice tool resulted from the following research paper.

  – Using Compressed Bytecode Traces for Slicing Java Programs, by Tao Wang and Abhik Roychoudhury, Intl. Conf. on Software Engineering (ICSE) 2004.

  The JSlice tool can be downloaded from `http://jslice.sourceforge.net/`
  Its current user base includes over 200 different research/industrial groups spread over 30 different countries.

- *Chronos, a Worst-case Execution Time (WCET) analysis tool for C programs.*
  Estimating the maximum execution time of a program is a generic problem. To obtain such estimates tightly, one needs to analyze the program flow as well as the the timing effects of the underlying processor micro-architecture. Such execution time estimates are directly useful for scheduling of hard real-time systems as well as in other applications (like guiding program optimizations). Our execution time analysis tool resulted from several research papers, including the core modeling which was reported in the following.

  – Modeling Out-of-order Processors for WCET Analysis, by Xianfeng Li, Abhik Roychoudhury and Tulika Mitra, Real-Time Systems Journal 2006, Preliminary version published in IEEE Real-time Systems Symposium (RTSS) 2004.

  The tool is available from `http://www.comp.nus.edu.sg/~rpembed/chronos`
  Its current user base includes over 100 different research groups in 16 different countries.

Research Citations

- *Total number of citations* $\sim$ 5400. All citation data has been collected from Google Scholar as of early 2019.

- h-index = 41, as of early 2019. h-index is the maximum value of h such that there are h papers co-authored by me with h or more citations.

- Paper with maximum citations is SemFix (ICSE 2013), with 325+ citations as of early 2019.

Publication List

(*Publications are grouped into two related areas. All papers are full-length papers unless indicated otherwise.*)

[1] `https://code.fb.com/developer-tools/getafix-how-facebook-tools-learn-to-fix-bugs-automatically/`

- **Trustworthy Software, Software Testing and Analysis**
  - [**CACM**] "Automated Program Repair", Claire Le Goues, Michael Pradel, Abhik Roychoudhury *Communications of the ACM*, To appear.
  - [**TSE'19**] "Coverage-based Greybox Fuzzing as Markov Chain", Marcel Böhme, Van Thuan Pham, Abhik Roychoudhury *IEEE Transactions on Software Engineering (TSE), To appear. (expanded version of CCS16 paper).*
  - [**NDSS'19**] "Neuro-Symbolic Execution: Augmenting Symbolic Execution with Neural Constraints" Shiqi Shen, Shweta Shinde, Soundarya Ramesh, Prateek Saxena, Abhik Roychoudhury *26th Network and Distributed System Security Symposium (NDSS) 2019.*
  - [**TOSEM'18**] "Test-equivalence Analysis for Automatic Patch Generation", Sergey Mechtaev, Xiang Gao, Shin Hwei Tan, Abhik Roychoudhury *ACM Transactions on Software Engineering and Methodology (TOSEM), 27(4), October 2018.*
  - [**TCAD'18**] "Symbolic Verification of Cache Side Channel Freedom", Sudipta Chattopadhyay, Abhik Roychoudhury ACM International Conference on Embedded Software (EMSOFT) 2018. *Published as IEEE Transactions on Computer Aided Design (TCAD), 37(11), pages 2812-2823, November 2018.*
  - [**FSE'18**] "Symbolic Execution with Existential Second-order Constraints", Sergey Mechtaev, Alberto Griggio, Alessandro Cimatti, Abhik Roychoudhury *ACM Symposium on Foundations of Software Engineering (FSE) 2018.*
  - [**ASE'18**] Android Testing via Synthetic Symbolic Execution Xiang Gao, Shin Hwei Tan, Zhen Dong, Abhik Roychoudhury *ACM/IEEE International Conference on Automated Software Engineering (ASE) 2018.*
  - [**ICSE'18**] "Semantic Program Repair Using a Reference Implementation", Sergey Mechtaev, Manh-Dung Nguyen, Yannic Noller, Lars Grunske, Abhik Roychoudhury *ACM/IEEE 40th International Conference on Software Engineering (ICSE) 2018.*
  - [**ICSE'18**] "Repairing Crashes in Android Apps", Shin Hwei Tan, Zhen Dong, Xiang Gao, Abhik Roychoudhury, *ACM/IEEE 40th International Conference on Software Engineering (ICSE) 2018.*
  - [**EmSE'18**] "A Correlation Study between Automated Program Repair and Test-suite Metrics", Jooyong Yi, Shin Hwei Tan, Sergey Mechtaev, Marcel Böhme, Abhik Roychoudhury *Empirical Software Engineering Journal, 23(5), pages 2948-2979, 2018.*
  - [**TSE'18**] "EnergyPatch: Repairing Resource Leaks to Improve Energy-efficiency of Android Apps", Abhijeet Banerjee, Lee Kee Chong, Clement Ballabriga and Abhik Roychoudhury *IEEE Transactions on Software Engineering (TSE), 44(5), pp 470-490, May 2018.*
  - [**CCS'17**] "Directed Greybox Fuzzing", Marcel Böhme, Van-Thuan Pham, Manh-Dung Nguyen, Abhik Roychoudhury, *24th ACM Conference on Computer and Communications Security (CCS) 2017.*
  - [**FSE'17**] "A Feasibility Study of Using Automated Program Repair for Introductory Programming Assignments", Jooyong Yi, Umair Z. Ahmed, Amey Karkare, Shin Hwei Tan, Abhik Roychoudhury *ACM SIGSOFT International Symposium on Foundations of Software Engineering (FSE) 2017.*
  - [**FASE'17**] "Bucketing Failing Tests via Symbolic Analysis", Van Thuan Pham, Sakaar Khurana, Subhajit Roy and Abhik Roychoudhury, *20th International Conference on Fundamental Approaches to Software Engineering (FASE) 2017.*

– [**ICSE'17-Poster**] Codeflaws: a programming competition benchmark for evaluating automated program repair tools, SH Tan, J Yi, S Mechtaev, A Roychoudhury Proceedings of the *39th International Conference on Software Engineering, 2017*, Poster paper.

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– [**ICSE'15**] "Hercules: Reproducing Crashes in Real-World Application Binaries", Van Thuan Pham, Wei Boon Ng, Konstantin Rubinov, Abhik Roychoudhury, *ACM/IEEE International Conference on Software Engineering (ICSE) 2015.*

– [**ICSE'15**] "DirectFix: Looking for Simple Program Repairs", Sergey Mechtaev, Jooyong Yi, Abhik Roychoudhury, *ACM/IEEE International Conference on Software Engineering (ICSE) 2015.*

– [**ICSE'15**] "Relifix: Automated Repair of Software Regressions", Shin Hwei Tan, Abhik Roychoudhury, *ACM/IEEE International Conference on Software Engineering (ICSE) 2015.*

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– [**WCRE'12**] "Modeling Software Execution Environment", Dawei Qi, William Sumner, Feng Qin, Mai Zheng, Xiangyu Zhang, Abhik Roychoudhury *19th IEEE Working Conference on Reverse Engineering (WCRE), 2012.*

– [**ICWS'12**] "Tenant Onboarding in Evolving Multi-tenant Software-as-a-Service Systems", Lei Ju, Bikram Sengupta, Abhik Roychoudhury *IEEE International Conference on Web Services (ICWS), 2012.*

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– [**TACAS'00**] "Verification of Parameterized Systems using Logic Program Transformations" Abhik Roychoudhury, K. Narayan Kumar, C.R. Ramakrishnan, I.V. Ramakrishnan and Scott A. Smolka, *International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS) 2000, Springer Verlag, LNCS vol 1785.*

– [**CADE'00**] "Formal MetaTheory using Implicit Syntax, and an Application to Data Abstraction for Asynchronous Systems", Amy P. Felty, Douglas J. Howe and Abhik Roychoudhury, *International Conference on Automated Deduction (CADE) 1999, Springer Verlag, LNCS 1632.*

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- [**PLILP/ALP'98**] "Logic Programming and Model Checking", Baoqiu Cui, Yifei Dong, Xiaoqun Du, K. Narayan Kumar, C.R. Ramakrishnan, I.V. Ramakrishnan, Abhik Roychoudhury, Scott A. Smolka and David S. Warren *PLILP/ALP 1998, Springer Verlag, LNCS 1490.*

• **Analysis of Embedded and Mobile Software**

- [**MOBILESoft'17**] "Future of Mobile Software for Smartphones and Drones: Energy and Performance", Abhijeet Banerjee and Abhik Roychoudhury *4th IEEE/ACM International Conference on Mobile Software Engineering and Systems (MOBILESoft) 2017.*
- [**MOBILESoft'16**] "Debugging Energy-efficiency related field failures in Mobile apps" Abhijeet Banerjee, Haifeng Guo and Abhik Roychoudhury *IEEE/ACM International Conference on Mobile Software Engineering and Systems (MOBILESoft) 2016.*
- [**MOBILESoft'16**] "Automated Re-factoring of Android Apps to enhance Energy-efficiency" Abhijeet Banerjee and Abhik Roychoudhury *IEEE/ACM International Conference on Mobile Software Engineering and Systems (MOBILESoft) 2016.*
- [**ADCOM**] "On Testing Embedded Software" Abhijeet Banerjee, Sudipta Chattopadhyay, Abhik Roychoudhury *Survey article in Advances in Computers, January 2016.*
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– [**LCTES'11**] "Static Bus Schedule aware Scratchpad Allocation in Multiprocessors", Sudipta Chattopadhyay and Abhik Roychoudhury *ACM SIGPLAN/SIGBED Conference on Languages, Compilers and Tools for Embedded Systems (LCTES) 2011.*

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– [**CODES+ISSS'08**] "Scratchpad Allocation for Concurrent Embedded Software ", Vivy Suhendra, Abhik Roychoudhury and Tulika Mitra, *ACM Intl. Conference on Hardware/Software Codesign and System Synthesis (CODES+ISSS) 2008*

– [**CODES+ISSS'08**] "Cache-aware Optimization of BAN Applications", Yun Liang, Lei Ju, Samarjit Chakraborty, Tulika Mitra and Abhik Roychoudhury, *ACM Intl. Conference on Hardware/Software Codesign and System Synthesis (CODES+ISSS) 2008*

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- [**ISSS'02**] "Timing Analysis of Embedded Software for Speculative Processors", Tulika Mitra, Abhik Roychoudhury and Xianfeng Li, *ACM International Symposium on System Synthesis (ISSS) 2002.*

- **Other Papers**
  - [**ICCL'98**] "A Conservative Technique to Improve Deterministic Evaluation of Logic Programs", Abhik Roychoudhury, C.R. Ramakrishnan, I.V. Ramakrishnan and R.C. Sekar, *IEEE International Conference on Computer Languages (ICCL) 1998.*
  - [**PAP'97**] "A rule-based data standardizer for Enterprise Databases", Abhik Roychoudhury, I.V. Ramakrishnan and Terrence Swift, *International Conference on Practical Applications of Prolog (PAP) 1997.*
  - [**FST&TCS'95**] "Efficient algorithms for vertex arboricity of planar graphs", Abhik Roychoudhury and Susmita Sur Kolay, *Intl. Conf. on Foundations of Software Technology and Theoretical Computer Science (FST & TCS) 1995, Springer Verlag, LNCS 1026.*

Service to the International Community (Recent ones only)

- Industrial Advisory Board Member, London Office of Rapid Cyber-security Advancement (LORCA), from 2018.
- Editorial board member, IEEE Transactions on Software Engineering (TSE), 2014 to 2018.
- General Chair, ACM SIGSOFT Symposium on Foundations of Software Engineering (FSE) 2022.
- Co-organizer, Dagstuhl Seminar on Automated Program Repair, January 2017.
- Program Chair, International Symposium on Software Testing and Analysis (ISSTA) 2016.
- Co-chair of New Ideas and Emerging Results (NIER), International Conference on Software Engineering (ICSE), 2015.
- Mentoring co-chair, International Conference on Software Engineering (ICSE) 2014.
- Doctoral Symposium co-chair, ACM SIGSOFT International Symposium on Foundations of Software Engineering (FSE) 2014.
- Invited International Member of ArtistDesign, the European Network of Excellence in Embedded Systems, 2009-12.
- Chair of Design and Verification Track in IEEE Real time Systems Symposium (RTSS) 2012.
- Program Chair of 9th International Colloquium on Theoretical Aspects of Computing (ICTAC) 2012, Proceedings available as Springer LNCS 7521.

- Co-chair of "Workshop on Future of Software Debugging", organized under Mysore Park Workshop Series, Infosys, Feb - March 2012.
- Recent Program Committee Memberships include:
  - International Conference on Software Engineering (ICSE) 2016, 2017 (Program Board), 2019(Program Board), 2020 (Program Board).
  - ACM SIGSOFT Foundations of Software Engineering (FSE) 2012, 2017, 2019.
  - IEEE Real-time Systems Symposium (RTSS) 2010, 11, 12, 13, 14.
  - ACM International Symposium on Software Testing and Analysis (ISSTA) 2013, 2015, 2016.
  - IEEE/ACM International Conference on Automated Software Engineering (ASE) 2013, 2018.
  - IEEE Intl. Conf. on Software Testing, Verification and Validation (ICST) 2013, 2014, 2015, 2017, 2019.
  - Intl. Conf. on Languages, Compilers, Tools and Theory for Embedded Systems (LCTES) 2012, 2014.
  - Intl. Conf on Embedded Software (EMSOFT) 2015.
  - Design Automation and Test in Europe (DATE) 2012.
  - International Conference on Theoretical Aspects on Computing (ICTAC) 2009, 13.
  - International Symposium on Automated Technology for Verification and Analysis (ATVA) 2009, 11, 12, 13.

Service to University and Local Community (Selected)

- Director, National Satellite of Excellence in Trustworthy Software Systems, from January 2019.
- Academic Director and Lead Principal Investigator of *Singapore Cyber-Security Consortium* (a consortium of 40+ companies), 2016-2022.
  I also serve as the chairman of the Management Committee of the Consortium. The consortium is anchored at NUS. I was heavily involved in setting up this first industry Consortium in Computer Science, at Singapore. The Consortium provides a platform for research engagement between member companies, academia and government agencies.
- Vice Dean of Graduate Studies, at NUS School of Computing, 2013 -16.
  Started several efforts to engage PhD students with industry, including an annual Placement workshop held at NUS School of Computing.
- Assistant Dean of Graduate Studies at NUS School of Computing, 2011 - 2013.
  Started an annual workshop series for greater engagement with students and professors from Indian universities in graduate eduction and research.
- Area representative of Security research area in Computer Science Department Executive Committee (CS ExCo) 2013-16.
- Chair of the *Publications Committee*, CS Department, NUS, 2010 - 13.
  Co-ordinated a year-long exercise to develop research evaluation metrics which balance the importance given to research activity vis-a-vis long-term research impact.
- Associate Professor representative in the NUS School of Computing, Executive Committee 2010.

- Member of *Graduate Studies Committee*, NUS School of Computing since 2003.
  Conducted many outreach trips to Indian universities since 2003, and to universities in Vietnam (2007).
- Member of *Outreach committee*, NUS School of Computing, 2009-11.
- Member of Selection Panel for Computing Alumni Assistance Award (CAAA) and Computing Student Development Fund (CSD), 2009-12.
- Member of Departmental Evaluation Committee (DEC) of various academic staff for promotion and tenure (on ad-hoc basis).
- Assistant Professor Representative in Executive Committee of School of Computing (2002-03).
- Speaker at Governmentware 2014, Organized by Ministry of Home Affairs, Strategies empowered by Training Session, 25 September 2014, Singapore.
- Invited speaker at Cognizant Quality Engineering and Assurance Summit, organized by Cognizant Singapore, March 6 2013.
- Research Project Evaluator for *Singapore Israel Industrial Development Foundation (SIIRD)*, Feb 2009.
- Member of Scientific Committee for *National Informatics Olympiad (NOI)*, Singapore (2002-2004). NOI is a creative problem solving and programming competition for High School / JC Students. Selected candidates from NOI represent Singapore in the International Olympiad in Informatics" (IOI).

Personal Data

- Married, One son.
- Indian citizen.