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# Search Based Software Engineering

## 9th International Symposium, SSBSE 2017 Paderborn, Germany, September 9–11, 2017 Proceedings

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# Preface

On behalf of the SSBSE 2017 Program Committee, we are pleased to present the proceedings of the 9th International Symposium on Search Based Software Engineering.

This year SSBSE was hosted in Paderborn, Germany, continuing to bring together international researchers to exchange and discuss ideas and to celebrate the latest progress in this rapidly advancing field.

It was a privilege for us to serve as program chairs and we believe that the quality of the program reflects the excellent efforts of the authors, reviewers, keynote speakers, tutorial presenters, and organizers.

First and foremost we are grateful for the widespread participation and support from the SBSE community. This year, SSBSE attracted a large number of submissions–the technical track alone attracted 26 submissions from 14 countries, which is an increase compared with last year.

We would like to thank all the authors for their high-quality contributions. We had a triple-blind review process in place for the main track. Each submission was reviewed by at least three Program Committee members and followed by an online discussion. At the end of the review process:

- 12 papers were accepted to the research track (7 long and 5 short)
- 4 papers were accepted to the challenge track,
- 2 papers were accepted to the student track.

We would like to thank the Program Committee members for providing timely, detailed, and constructive feedback, and for actively participating in the online discussions.

We also wish to thank the general chair, Lars Grunske, who brought SSBSE to Paderborn and put on, together with his team, such an enjoyable event. Special thanks are also due to:

- The track chairs of our specialist tracks:
  - David R. White and Tanja E.J. Vos for organizing an exciting challenge track;
  - Claire Le Goues for chairing the student and short paper tracks.
    Dr. Le Goues deserves additional credit for proposing to change the name from graduate to student track, allowing more participation from students; they are a vital part of any research field.
- Also, we especially thank Matheus Paixao (web chair) and Gregory Gay (publicity chair) for their precious help in reaching out to the community.

In addition to our technical sessions, covering a wide range of topics, SSBSE 2017 attendees had the opportunity to hear

- State-of-the-art reports from two esteemed keynote speakers: Myra B. Cohen and Joachim Wegener.
- Technical tutorials from: Gordon Fraser, Antonio J. Nebro, Dimo Brockhoff, and Hermann Kaindl.
- Journal first invited talk sessions.

We hope that, with these proceedings, anyone who did not have the chance to be with us in Paderborn, will have the opportunity to follow the latest advances of the SBSE community.

June 2017

Tim Menzies
Justyna Petke

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# Keynotes

# The Grass isn't Always Greener: A Changing Neighborhood and Varying Landscape

Myra B. Cohen

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**Abstract.** Search based software engineering has been used to solve many problems in software engineering and as such many different search based algorithms have been utilized for optimizing problems across the full software lifecycle. Solutions range from simple greedy to local heuristic search to evolutionary, population based techniques. Choosing the algorithm to use for a particular problem is a key design decision. However, an equally important decision, and one that is often less explored, is the design of the search neighborhood and the choice of its transformation operators. In this talk I will discuss some of our experience with varying the neighborhoods and transformation operators for problems such as software test generation and reverse engineering system models. I will show how this important design decision can have a large impact on the quality of a search algorithm for different variants of the same problem, because it fundamentally alters the search landscape. I will also show that while one neighborhood may be superior solving one variation of a problem, it may not work well at all for another variant of the same problem.

**Biography**: Myra Cohen is a Susan J. Rosowski Professor at the University of Nebraska-Lincoln where she has been a member of the Laboratory for Empirically Based Software Quality Research and Development, ESQuaReD since 2004. Her research expertise is in combinatorial testing and software testing of highly configurable software, software product lines, graphical user interfaces, and self-adaptive software. She regularly utilizes search based software engineering techniques in her research and teaches a graduate course on this topic. She has been a program committee member of many highly regarded software engineering conferences such as ICSE, FSE, ASE, ISSTA and ICST. She was the program co-chair of SSBSE in 2011, the GECCO SBSE track in 2010 and ISSRE in 2013. She was the general chair of ASE in 2015.

# Industrial Applications of Evolutionary Testing

Joachim Wegener

Berner & Mattner Systemtechnik GmbH, Berlin, Germany

**Abstract.** Test case design could be easily interpreted as the search of the tester for an error-sensitive set of test cases. The application of search techniques to find an adequate set of test cases automatically is straight forward if an appropriate transformation of the testing goals into a fitness function could be defined. Therefore, numerous publications on evolutionary testing were published during the last two decades from researchers all over the world. Nevertheless, evolutionary testing has not found its way into industrial practice. Industrial applications are mostly limited to experimental case studies. The keynote will present successful applications of evolutionary testing in industrial practice and will discuss the success factors. Most successful applications are from the test of embedded systems, since here often very complex implementations are required in order to realize single, well tangible system tasks. But also the aspects hindering a broader application of evolutionary testing in practice shall be discussed. The time is right for a wider introduction.

**Biography**: Dr. Joachim Wegener studied computer science at the Technical University Berlin and received his PhD from Humboldt University Berlin. His thesis work, Evolutionary Testing of real-time systems temporal behavior gained him the Best Dissertation in Software Engineering award of the Ernst-Denert-Foundation and the German Computer Society, 2002. Joachim Wegener began his professional career as a scientist at Daimler AG Research and Technology. For DaimlerChrysler research and advanced development he led the software analysis and testing group as well as a group on advanced techniques in software engineering. Since 2007 he works for Berner Mattner Systemtechnik GmbH a subsidiary of the Assystem group specialized on embedded systems development services and products. At Berner Mattner, Joachim Wegener is responsible for the departments in Berlin, Brunswick, Cologne and Wolfsburg as well as the product development. He is one of the international leading industrial researchers in evolutionary and systematic testing and has more than ninety publications. He is the inventor of the successful classification tree editors CTE, CTE XL and TESTONA with several thousand users worldwide.

# Tutorials

# Algorithms for Multiobjective Optimization and How to Benchmark Them

Dimo Brockhoff

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**Abstract.** Multiobjective optimization problems, in which two or more objective functions are to be optimized simultaneously, appear in many application domains. The field of search based software engineering is no exception. Various algorithms for multiobjective optimization have been proposed in recent years, with the effect that the ultimate practical question when solving a concrete problem became increasingly difficult: which of the many available algorithm shall I actually use? To contribute to the answer of this question, we revisit several common multiobjective optimization algorithms in this talk and discuss their strengths and weaknesses from a more theoretical perspective. In addition, we look at the latest developments on how to benchmark (multiobjective) algorithms and showcase the performance of some common (and not so common) algorithms on the 55 unconstrained numerical blackbox functions of the biobjective BBOB test suite.

**Biography**: Dimo Brockhoff received his diploma in computer science from University of Dortmund, Germany in 2005 and his PhD (Dr. sc. ETH) from ETH Zurich, Switzerland in 2009. Later, he held two postdoctoral research positions in France at Inria Saclay Ile-de-France (2009-2010) and at Ecole Polytechnique (2010-2011) before joining Inria in November 2011 as a permanent researcher. After working at Inrias Lille - Nord Europe research center for about five years, he has been back to the Saclay - Ile-de-France center since October 2016 to become member of the new Randomized Optimization team. His research interests are focused on evolutionary multiobjective optimization (EMO), in particular on theoretical aspects of indicator-based search, and on the benchmarking of blackbox algorithms in general. Dimo has been involved in the co-organization of several special issues and workshops around these topics such as the SIMCO and SAMCO workshops at the Lorentz center in the Netherlands in 2013 and 2016 and the Blackbox Optimization Benchmarking workshops at CEC 2015 and at GECCO 2013, 2015, and 2016.

# Search-based Unit Test Generation with EvoSuite

Gordon Fraser

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**Abstract.** EvoSuite automatically generates test cases with assertions for classes written in Java code, using a search-based approach that evolves whole test suites towards satisfying a coverage criterion. For the produced test suites, EvoSuite suggests possible oracles by adding small and effective sets of assertions that concisely summarize the current behavior; these assertions allow the developer to detect deviations from expected behavior, and to capture the current behavior in order to protect against future defects breaking this behaviour. In this tutorial, we will discuss how to use of the EvoSuite search-based test generation infrastructure to apply search-based test generation, and how to build on EvoSuite to develop new techniques using, or extending, search-based testing.

**Biography:** Gordon Fraser is a Senior Lecturer in Computer Science at the University of Sheffield, UK. He received his Ph.D. from Graz University of Technology, Austria, in 2007, and worked as a post-doc researcher at Saarland University, Germany. He has published on improving software quality and programmer productivity at all major software engineering venues (e.g., TSE, TOSEM, ICSE, ISSTA, FSE, ASE, ICST). He is chair of the steering committees of the International Conference on Software Testing, Verification, and Validation (ICST) and the Symposium on Search-Based Software Engineering (SSBSE). He has been programme chair of several testing-related conferences (ICST, TAP, TAIC PART, SSBSE) and workshops, is a regular member of many programme and organising committees in the field (e.g., ICSE, FSE, ASE, ISSTA), and is editorial board member of the IEEE Transactions on Software Engineering (TSE) and Software Testing, Verification, and Reliability (STVR) journals. He is a founder and one of the core developers of the EvoSuite search-based unit test generator.

# Optimization Search for GUIs and Cyberphysical Systems

Hermann Kaindl

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**Abstract.** This tutorial presents and contrasts two different optimization search approaches studied by this proposer for automated GUI generation and for feature interactions in cyberphysical automotive systems. Providing several GUIs tailored for multiple devices (desktop PCs, tablet PCs and smartphones) is desirable but expensive, and it takes time. Our new approach just requires a device specification with a few parameters for automated GUI tailoring in the course of designtime generation from the same highlevel interaction design model. This tailoring is implemented as heuristic optimization search.

With increasing numbers of features in automotive systems, feature interaction (FI) becomes more and more relevant regarding safety and emissions. Our new approach for optimization of feature interactions integrates an optimization objective (minimize CO2 emission) with both soft and hard constraints (e.g., related to certain temperatures). In the course of iterations of hillclimbing optimization at runtime, the integrating objective function is dynamically adapted for heuristic coordination of FIs.

These approaches will be contrasted primarily in terms of the very different application domains and, more fundamentally, regarding designtime vs. runtime optimization with their very different requirements.

**Biography**: Hermann Kaindl joined the Institute of Computer Technology at TU Wien in Vienna, Austria, in early 2003 as a full professor. Prior to moving to academia, he was a senior consultant with the division of program and systems engineering at Siemens Austria. There he has gained more than 24 years of industrial experience in software development and humancomputer interaction. He has published five books and more than 220 papers in refereed journals, books and conference proceedings, and he has previously run more than 50 tutorials. He is a Senior Member of the IEEE and a Distinguished Scientist Member of the ACM, and he is on the executive board of the Austrian Society for Artificial Intelligence. In the past, Hermann Kaindl published his basic research on Heuristic Search in Artificial Intelligence in the AIJ, several IEEE Transactions, and in many Conference Proceedings of IJCAIs, AAAIs and ECAIs.

# Multi-objective Optimization with the jMetal Framework. Applications to SBSE

Antonio J. Nebro

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**Abstract.** jMetal is a Java-based framework for multi-objective optimization with metaheuristics which has become popular in some disciplines, including Search Based Software Engineering (SBSE). In this tutorial, we give a practical overview of the main jMetal components (algorithms, encodings, problems, operators, experiments, quality indicators), focusing on how to configure and run some of the included algorithms and also on how to incorporate new solution representations and problems. We give examples of classical algorithms but also more modern techniques, including preference-based metaheuristics. Some SBSE problems will be used as case studies.

**Biography**: Antonio J. Nebro received his M.S. and Ph.D. degrees in Computer Science from the University of Malaga, Spain, in 1992 and 1999, respectively. He is currently an Associate Professor of Computer Science at the University of Malaga, Spain. His current research activity is related to multi-objective optimization techniques, parallelism and Big Data, and the application of these techniques to real-world problems of the domains of bioinformatics and civil engineering. He has coauthored 30 articles published in international journals, 28 of which are indexed in JCR, 15 book chapters and more than 30 articles in international conferences. His H index is 30, and his papers have more than 3250 citations. He is one of the designers and main developer of the jMetal framework for multi-objective optimization with metaheuristics.

# Journal-First Presentations

# A Systematic Mapping Study of Search-based Software Engineering for Software Product Lines

Roberto E. Lopez-Herrejon, Lukas Linsbauer, and Alexander Egyed

**Abstract. Context**: Search-Based Software Engineering (SBSE) is an emerging discipline that focuses on the application of search-based optimization techniques to software engineering problems. Software Product Lines (SPLs) are families of related software systems whose members are distinguished by the set of features each one provides. SPL development practices have proven benefits such as improved software reuse, better customization, and faster time to market. A typical SPL usually involves a large number of systems and features, a fact that makes them attractive for the application of SBSE techniques which are able to tackle problems that involve large search spaces.

**Objective**: The main objective of our work is to identify the quantity and the type of research on the application of SBSE techniques to SPL problems. More concretely, the SBSE techniques that have been used and at what stage of the SPL life cycle, the type of case studies employed and their empirical analysis, and the fora where the research has been published. **Method**: A systematic mapping study was conducted with five research questions and assessed 77 publications from 2001, when the term SBSE was coined, until 2014.

**Results**: The most common application of SBSE techniques found was testing followed by product configuration, with genetic algorithms and multi-objective evolutionary algorithms being the two most commonly used techniques. Our study identified the need to improve the robustness of the empirical evaluation of existing research, a lack of extensive and robust tool support, and multiple avenues worthy of further investigation. **Conclusions**: Our study attested the great synergy existing between both fields, corroborated the increasing and ongoing interest in research on the subject, and revealed challenging open research questions.

**Inf. Softw. Technol. 61, C (May 2015), 33–51**

# Technical Debt Reduction Using Search Based Automated Refactoring

Michael Mohan, Des Greer, and Paul McMullan

**Abstract.** Software refactoring has been recognized as a valuable process during software development and is often aimed at repaying technical debt. Technical debt arises when a software product has been built or amended without full care for structure and extensibility. Refactoring is useful to keep technical debt low and if it can be automated there are obvious efficiency benefits. Using a combination of automated refactoring techniques, software metrics and meta-heuristic searches, an automated refactoring tool can improve the structure of a software system without affecting its functionality. In this paper, four different refactoring approaches are compared using an automated software refactoring tool. Weighted sums of metrics are used to form different fitness functions that drive the search process towards certain aspects of software quality. Metrics are combined to measure coupling, abstraction and inheritance and a fourth fitness function is proposed to measure reduction in technical debt. The 4 functions are compared against each other using 3 different searches on 6 different open source programs. Four out of the 6 programs show a larger improvement in the technical debt function after the search based refactoring process. The results show that the technical debt function is useful for assessing improvement in quality.

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