Dear members of the SPLC MIP Award Selection Committee,

we nominate the following paper for an SPLC Most Influential Paper Award:

"Automated and scalable t-wise test case generation strategies for software product lines" by Gilles Perrouin, Sagar Sen, Jacques Klein, Benoit Baudry, Yves Le Traon, published in the Third International Conference on Software Testing, Verification and Validation (ICST), 2010.

>> **Qualitative impact:** We believe this paper deserves the award for the following reasons:

- It pioneered the **product sampling line of research** in the domain of SPL Testing. In particular, the paper fostered a now very active line of research on product line sampling by bridging combinatorial interaction testing (CIT) with model-driven engineering in a complete framework. It did so by using a general metamodel (previously developed by the same authors) in order to encode all forms of Boolean feature models and transform them in the Alloy formal language.

- It **offered two heuristics to cope with the t-wise coverage** of feature models, known to be NP-complete in the presence of constraints. As a result, exact computation approaches struggled (and still struggle on the largest feature models today, despite impressive algorithmic and hardware advances) and the *divide-and-compose* strategies addressed this problem. Additionally, the study defined several metrics such as tuple occurrences or test case redundancies that **inspired follow-up techniques and studies on (dis)similarity-based sampling**, leading to highly scalable and flexible search-based approaches.

- **Established and simplified the use of CIT, for product line sampling,** so that it became easily accessible to people with limited knowledge of SAT solving techniques, offering solutions for any kind of feature model and any value of interaction strength. This is perhaps one of **the biggest merits of the paper.**

>> **Quantitative impact:** together with its journal extension[1] It has attracted **more than 460 citations** (286 citations in the conference version and 175 citations in the journal version). It is noted that the conference version is the most cited paper of ICST 2010.

This paper inspired many impactful follow-up approaches/papers such as:

- Sebastian Oster, Florian Markert, Philipp Ritter. *"Automated Incremental Pairwise Testing of Software Product Lines"*, SPLC 2010.

- Martin Fagereng Johansen, Øystein Haugen, and Franck Fleurey. *"Properties of Realistic Feature Models Make Combinatorial Testing of Product Lines Feasible"*, MODELS 2011.

- Malte Lochau, Ina Schaefer, Jochen Kamischke, Sascha Lity. *"Incremental Model-Based Testing of Delta-Oriented Software Product Lines"*, TAP@TOOLS 2012.

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[1] *Gilles Perrouin, Sebastian Oster, Sagar Sen, Jacques Klein, Benoit Baudry, Yves Le Traon: Pairwise testing for software product lines: comparison of two approaches. Software Quality Journal 20(3-4): 605-643 (2012)*

- Sven Apel, Alexander von Rhein, Philipp Wendler, Armin Größlinger, Dirk Beyer. *"Strategies for product-line verification: case studies and experiments"*, ICSE 2013.

- A. B. Sánchez, S. Segura and A. Ruiz-Cortés. *"A Comparison of Test Case Prioritization Criteria for Software Product Lines"*, ICST 2014.

- Thomas Thüm, Sven Apel, Christian Kästner, Ina Schaefer, Gunter Saake. *"A classification and survey of analysis strategies for software product lines"*, ACM Computing Surveys 2014.

- Christopher Henard, Mike Papadakis, Gilles Perrouin, Jacques Klein, Patrick Heymans, Yves Le Traon. *"Bypassing the Combinatorial Explosion: Using Similarity to Generate and Prioritize T-wise Test Configurations for Software Product Lines"*, TSE 2014.

- Christopher Henard, Mike Papadakis, Mark Harman, Yves Le Traon. *"Combining multi-objective search and constraint solving for configuring large software product lines"*, ICSE 2015.

- Flávio Medeiros, Christian Kästner, Márcio Ribeiro, Rohit Gheyi, Sven Apel. *"A comparison of 10 sampling algorithms for configurable systems"*, ICSE 2016.

- José A. Parejo, Ana B. Sánchez, Sergio Segura, Antonio Ruiz-Cortés, Roberto E. Lopez-Herrejon, and Alexander Egyed. *"Multi-objective test case prioritization in highly configurable systems"*, JSS 2016.

- Axel Halin, Alexandre Nuttinck, Mathieu Acher, Xavier Devroey, Gilles Perrouin and Benoit Baudry. *"Test them all, is it worth it? Assessing configuration sampling on the JHipster Web development stack"*, Empirical Software Engineering Journal 2019.

- Robert M. Hierons, Miqing Li, Xiaohui Liu, Jose Antonio Parejo, Sergio Segura, and Xin Yao. *"Many-Objective Test Suite Generation for Software Product Lines"*, ACM-TOSEM 2020.

>> **Supporting statements:** We list individual statements supporting the significance of the paper.

- *Sven Apel, Saarland University* -- Configuration sampling is a key technique in testing and analyzing software product lines. The nominated paper has proposed the first automated and scalable approach for configuration sampling in the context of software product lines. As such it has been a foundation for much follow-up work, this way, opening up a whole new, thriving subarea. What is notable is that this work, and the follow-up work, hit a nice sweet spot between theoretical considerations and practical applications. It inspired my work and the work of many other researchers.

- *Sergio Segura, University of Seville* -- The seminal paper by Perrouin et al. opened a whole new research agenda in SPL analysis and testing. Among others, it greatly inspired my work and that of others in the context of search-based test case selection and prioritization for SPLs (Hierons et al., Parejo et al. and Sánchez et al. studies). A must-read for anyone interested in SPLs and model-based testing.

- *Mark Harman, University College London* -- Perrouin et al. work should be among the "top-reads" in the history of SPL development. The large number of citations, at 460 already, is a testament to the intellectual impact of the work. Furthermore, the importance of both combinatorial testing and of software product lines in industry mean that this work is highly important and impactful for practicing software testers as well. I can think of no better candidate for the most influential paper

award than one that has impact on both the academic and industrial communities, which goes right to the founding principles of ICST, which has always prided itself in drawing together both academic and practitioner communities.

- ***Myra Cohen, Iowa State University*** -- This work uses feature modeling in a clever way to solve an important challenge of combinatorial interaction testing (CIT). Prior to this research, it was thought that SAT solving was not a viable approach for generating CIT samples due to scalability. In particular, achieving t-wise coverage higher than 2 was rarely feasible and research studies demonstrating its use were limited to toy examples. Through the use of two approaches that either divide and conquer or incrementally partition sets of constraints, this paper demonstrated that we can indeed scale SAT-based approaches for CIT generation to realistic problems. The use of Alloy as the (formal) front end modeling language means that the domain information (from the developers end) is retained and can be leveraged in decision making and additional analyses on the model can be performed. This work has led to multiple follow-on papers/studies which scale CIT to real/large applications.

- ***Mathieu Acher, Université of Rennes*** -- This paper opened a whole new research direction in software product line engineering and software testing. This work brought both a new problem (how to sample configurations while respecting constraints?), a new approach (using criterion to drive the testing strategy), and a solution with SAT solvers through Alloy. It is no surprise that multiple papers and studies build upon this paper, in the broad software engineering community but also in artificial intelligence with papers that now motivate their sampling work using the seminal work of Perrouin et al. Besides various sampling strategies are now investigated in the context of learning configuration spaces (e.g., for cost-effective performance prediction) and are also follow-up of Perrouin et al. I cannot imagine a course on software product lines without mentioning this article. Just as I cannot imagine a PhD student, an industrial collaborator, or a colleague interested in product lines not knowing this paper.

- ***Mike Papadakis, University of Luxembourg*** – The pioneering work of Perrouin et al. introduced the idea of smart product sampling in SPLs through combinatorial interaction testing (CIT), which inspired our work on similarity-based sampling and prioritization. Perrouin et al. work also demonstrated that SAT solving is the key element in generating and sampling valid products by handling the feature model constraints when attempting to cover any interaction strength level.

Individual confirmation on this joint nomination will be sent, by email, from each of us below.

Signed,

Sven Apel, *Saarland University, Germany*

Myra Cohen, *Iowa State University, United States*

Sergio Segura, *University of Seville, Spain*

Mathieu Acher, *Université of Rennes, France*

Mike Papadakis, *University of Luxembourg, Luxembourg*

Mark Harman, *University College London, United Kingdom*