Automated and Scalable T-wise Test Case Generation Strategies for Software Product Lines

Gilles Perrouin, Sagar Sen, Jacques Klein, Benoit Baudry, Yves Le Traon

SPLC 2024 MIP Award

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Automated and Scalable T-wise Test Case Generation Strategies for Software Product Lines

It's more a tale of a postdoc (and friends) venturing in uncharted testing lands….

Once upon a time…

Once upon a time…

It's me in 2007

(in case…)

Once upon a time…

In far far away…

It's me in 2007

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Once upon a time…

In far far away…

Not really…

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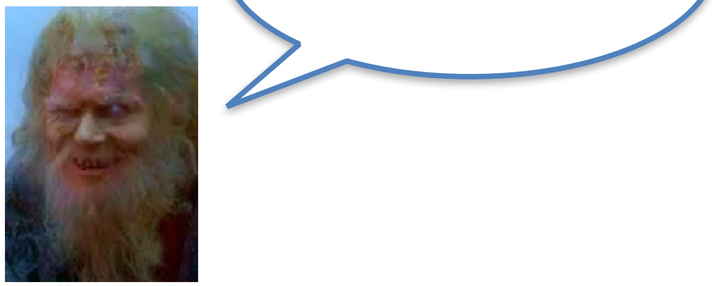

Once upon a time…

In far far away…

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What is your quest?

A flexible model-driven methodology to derive products for Software Product Lines

Once upon a time…

In far far away…

Not really…

It's me in 2007

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What is your quest?

How do you automate this ?

A flexible model-driven methodology to derive products for Software Product Lines

Once upon a time…

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A flexible model-driven methodology to derive products for Software Product Lines

I don't know…

What is your quest?

How do you automate this ?

Once upon a time…

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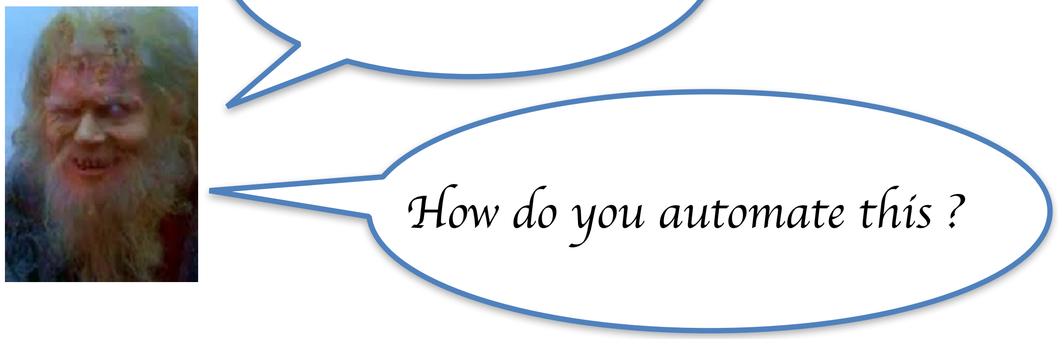

Answering the gate's keeper…

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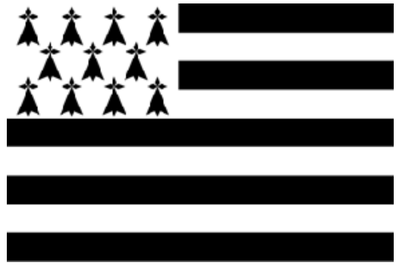

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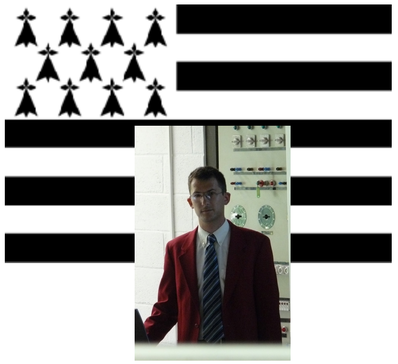

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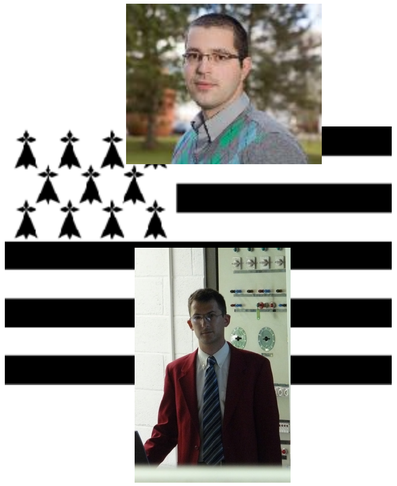

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Reconciling Automation and Flexibility in Product Derivation

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SPLC'08

Yes, but how do you ensure compositions are valid?

Another gate's keeper…

Yes, but how do you ensure compositions are valid?

Another gate's keeper…

Actually, the Phd's co-supervisor (P. Heymans)

Yes, but how do you ensure compositions are valid?

I don't know…

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Quest: Sampling products according to coverage criteria and check their validity

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Prof Yves Le Traon

Dr. Benoit Baudry

Sagar Sen (PhD Student)

Quest: Sampling products according to coverage criteria and check their validity

Validating the Scope of Model-driven Software Product Lines via Automatic Testing Strategies

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« although this is an internally consistent paper, it does not deliver on its claimed contributions » R2

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Minimal Test Set Generation for Software Product Lines

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« Why do we care how many configurations are needed?

It seems odd to read a testing paper that does not do any actual testing » R3

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There were some positive and constructive comments as well…

They led us to:

- *Not trying to complete the quest in one paper*
- *Better address related work*

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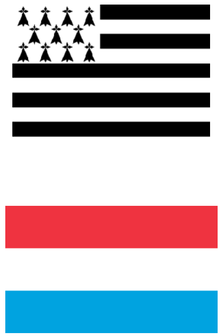

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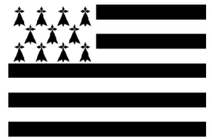

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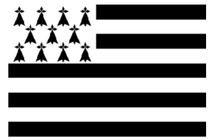

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ICST'10

Why this paper?

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Selecting configurations by covering ***all t-combinations*** of features ***at least once***, resulting in small test suites, likely to find interaction faults[1] (combinatorial interaction testing)

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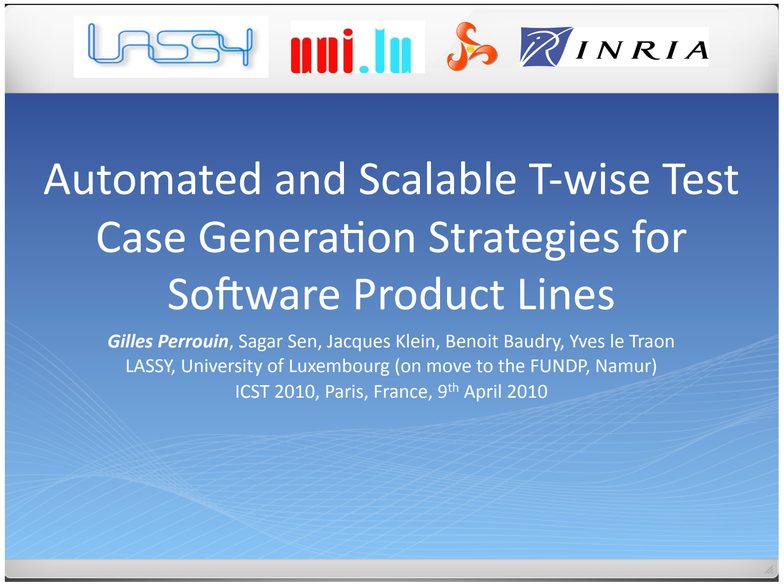
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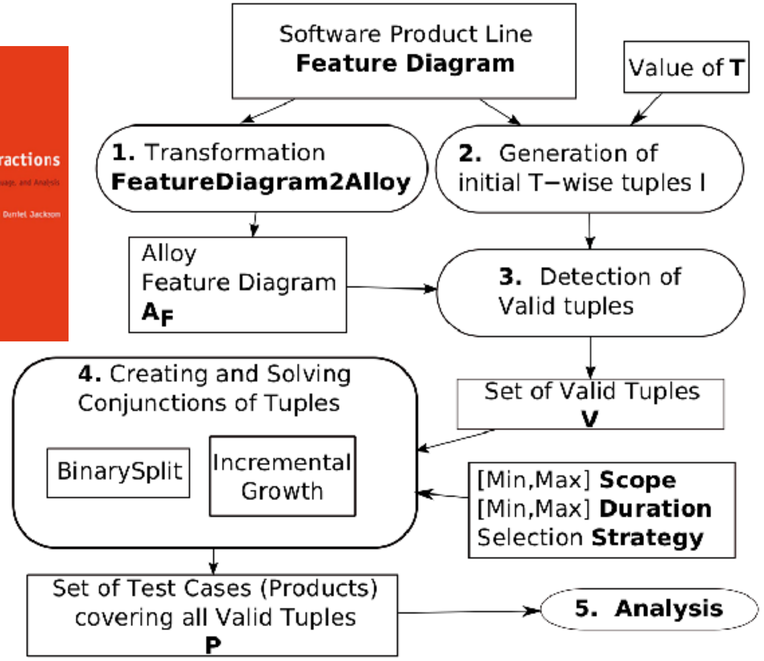

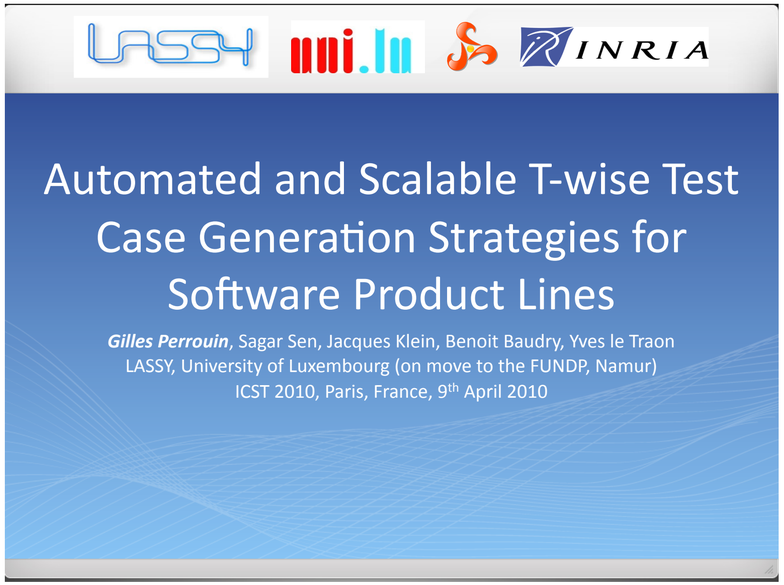

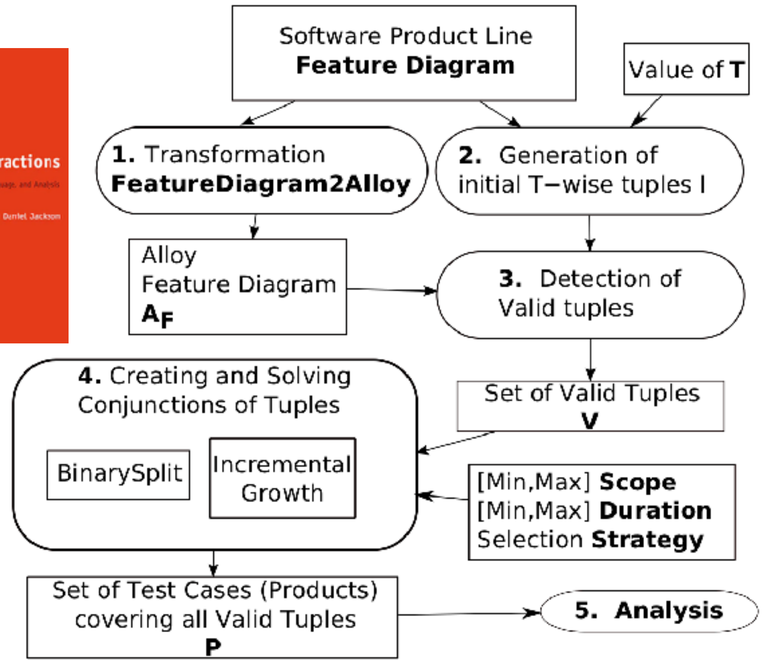

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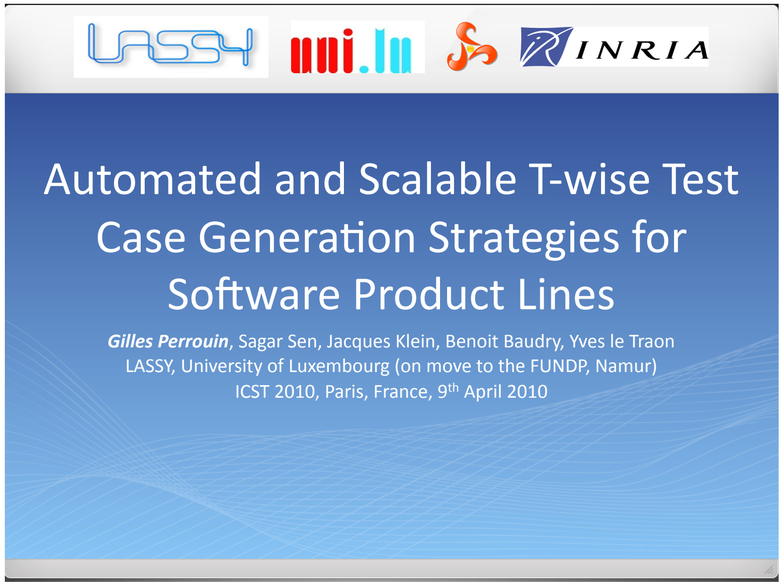

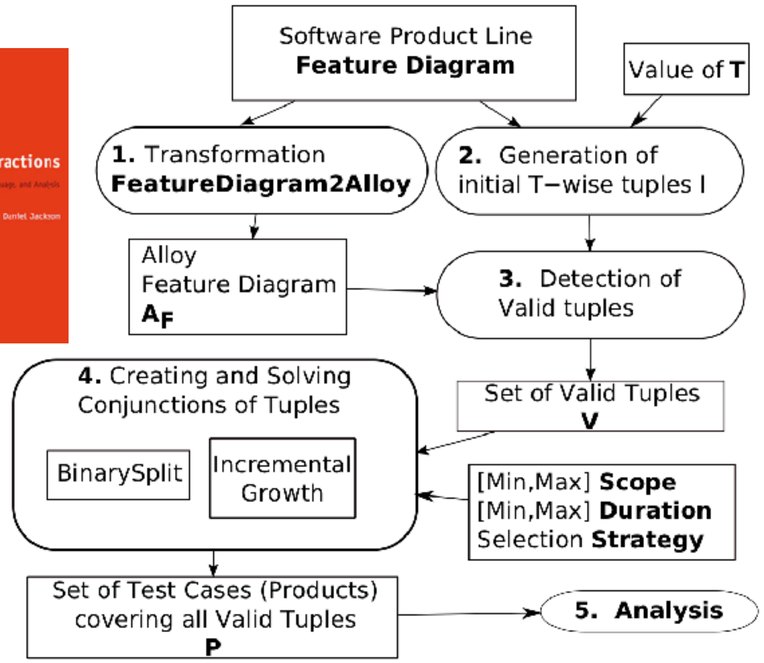

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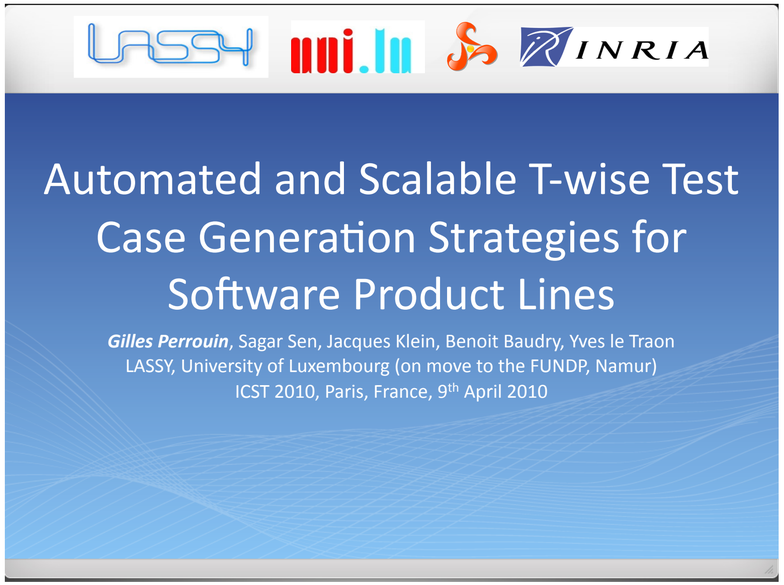

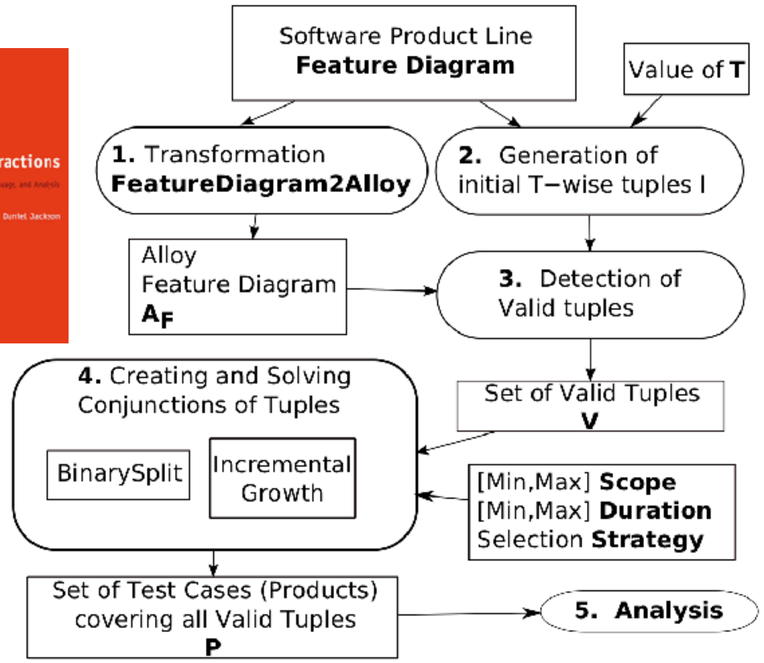

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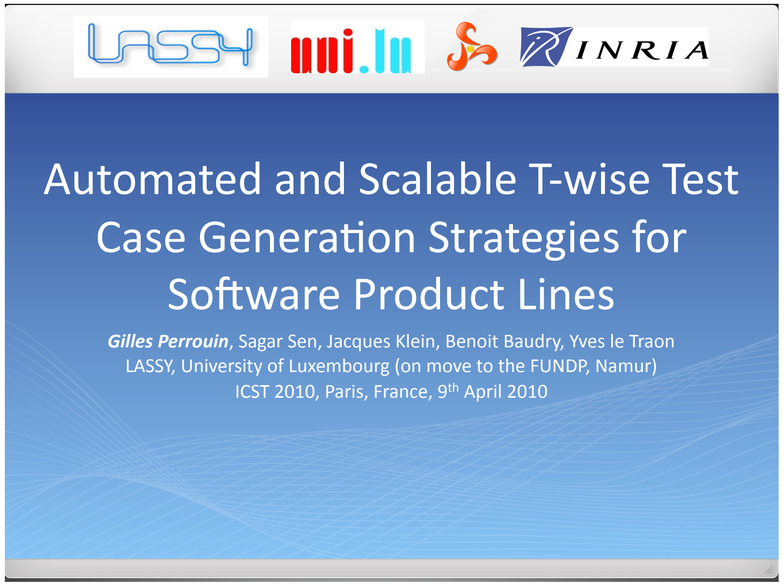

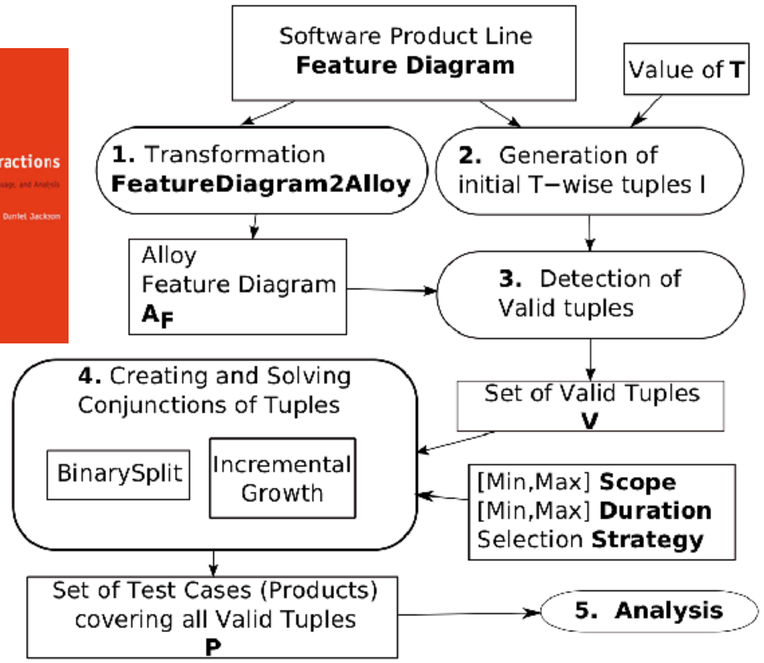

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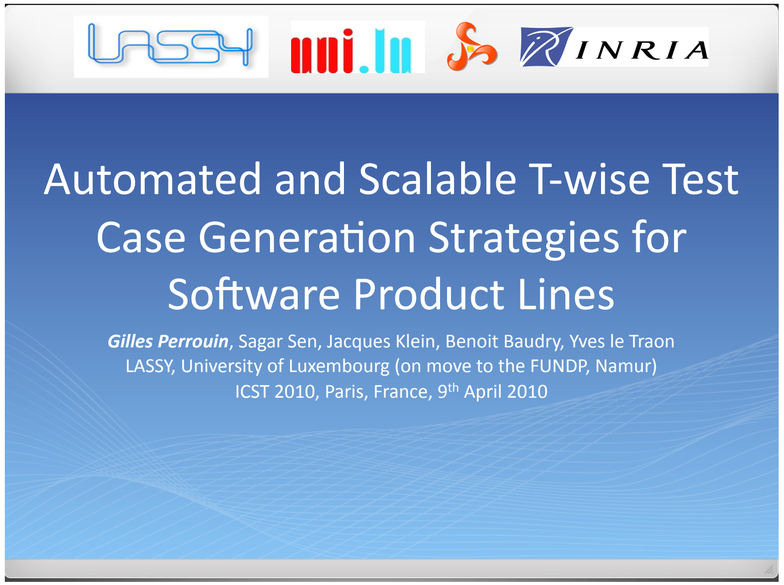

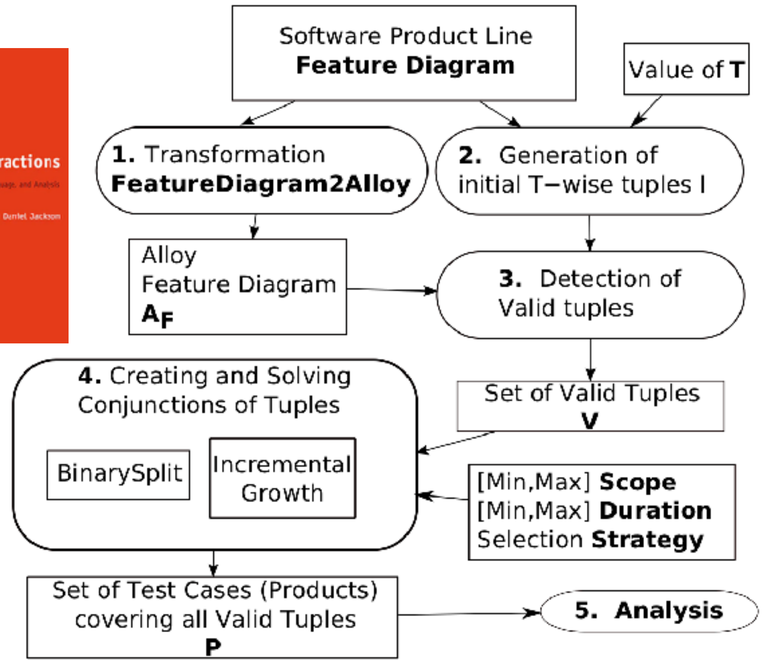

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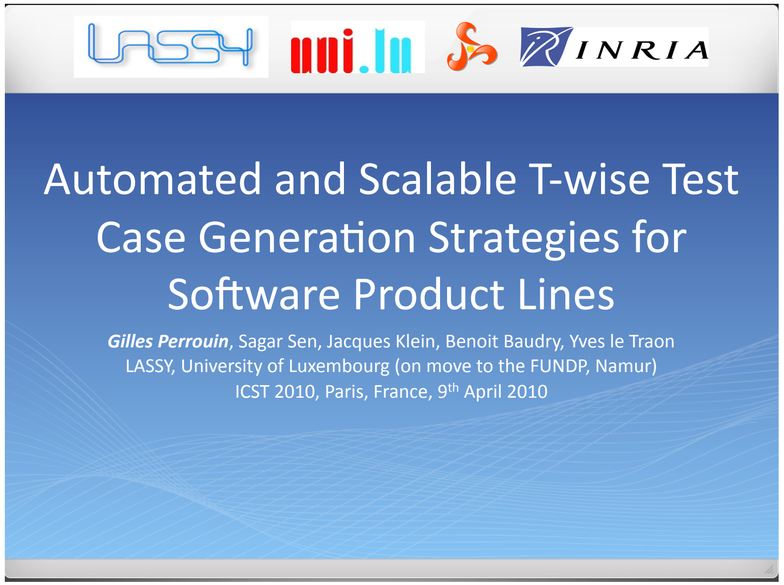

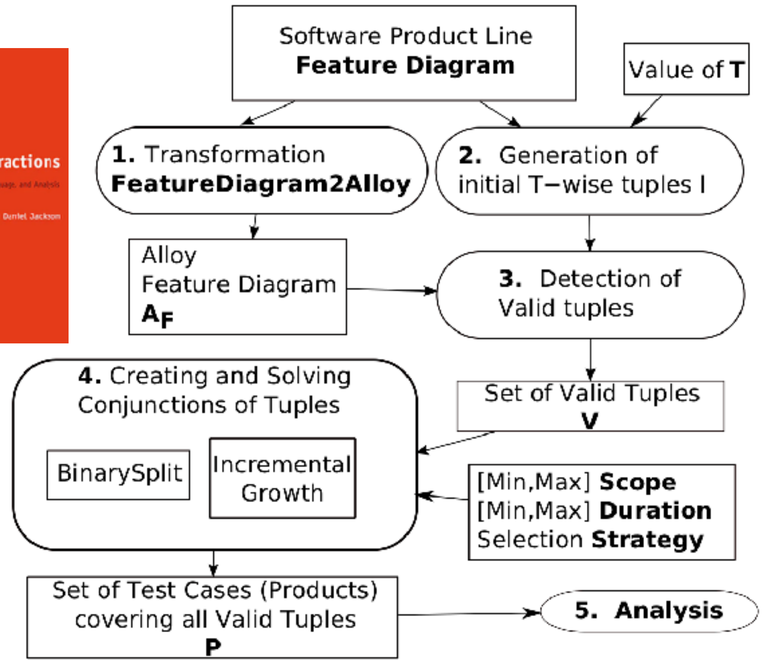

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- ***Metrics*** to assess test quality: number of products, occurence, ***« redundancy »*** (now known as similarity)

Experimental Results

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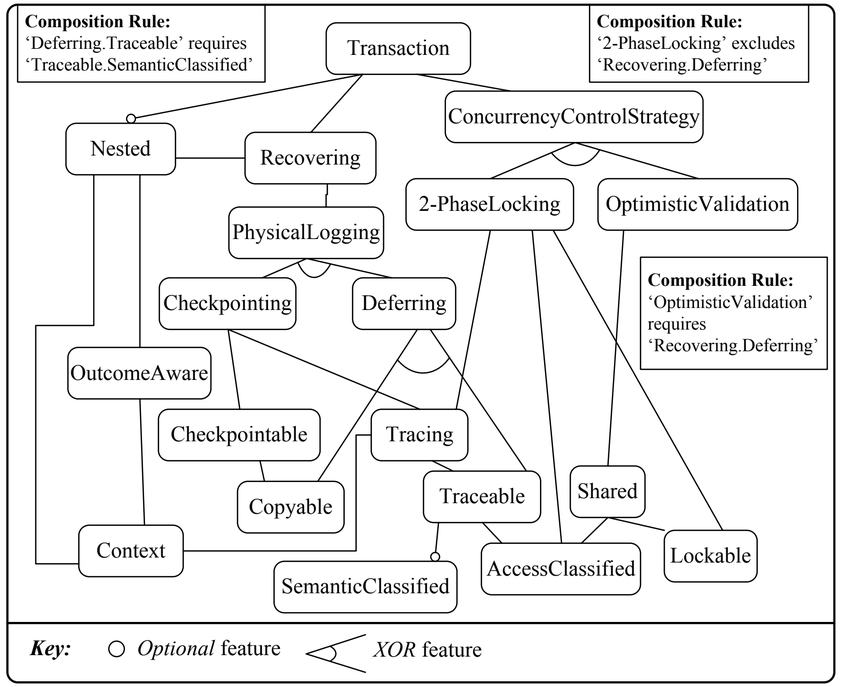

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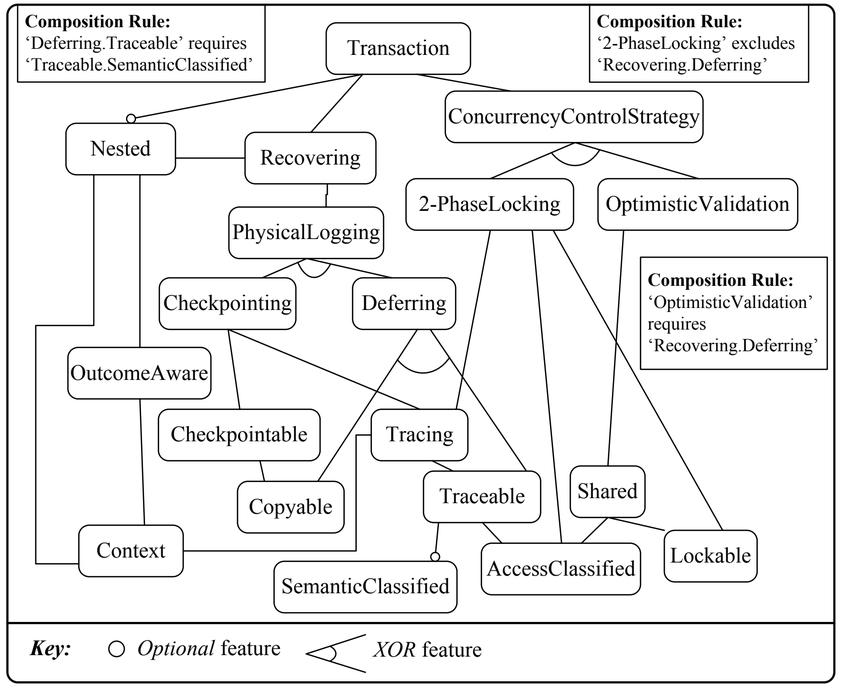

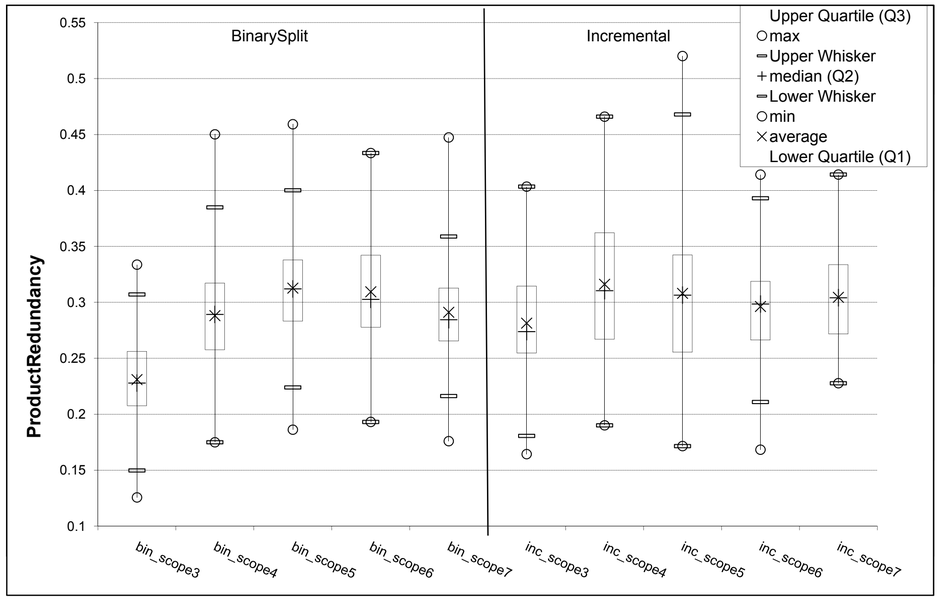

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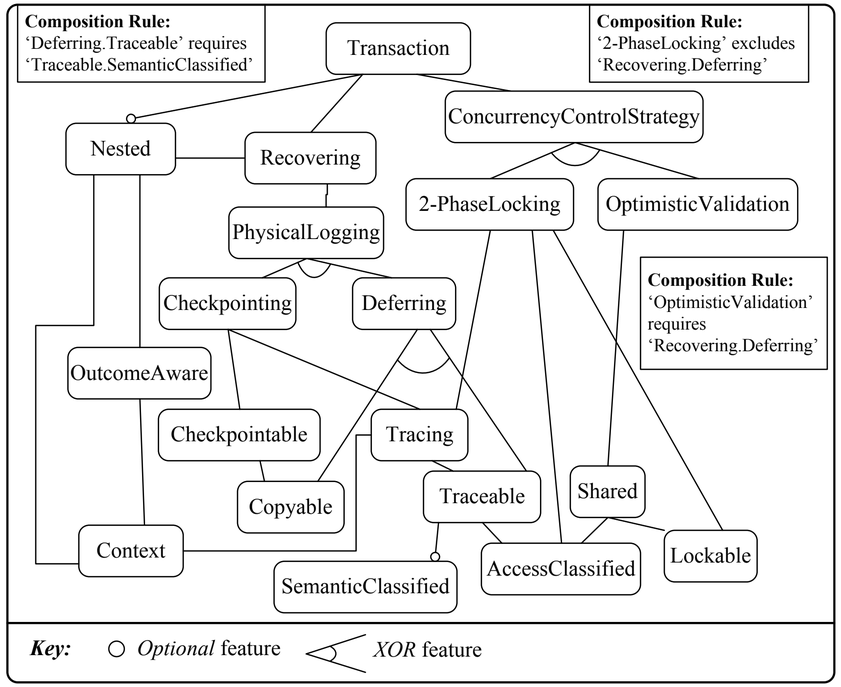

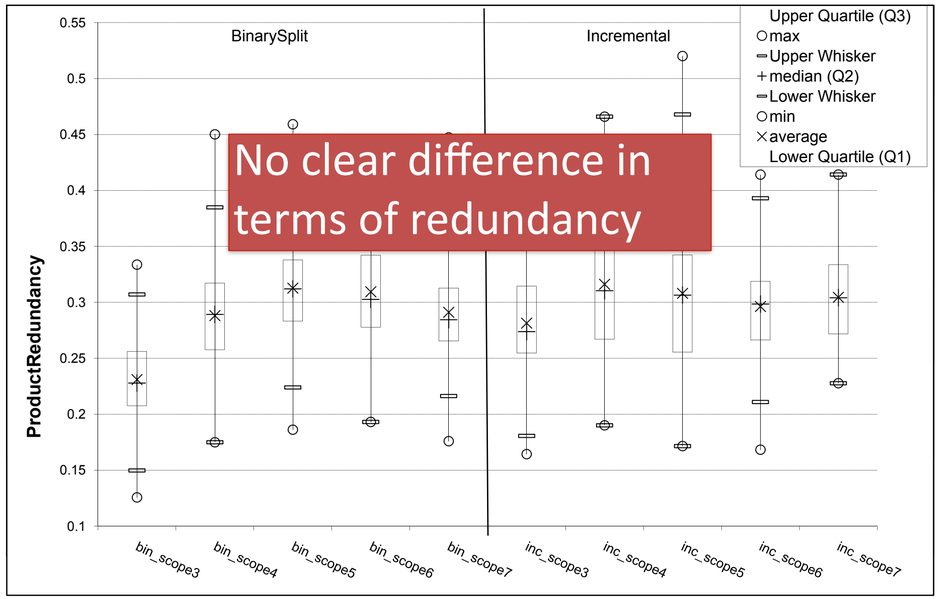

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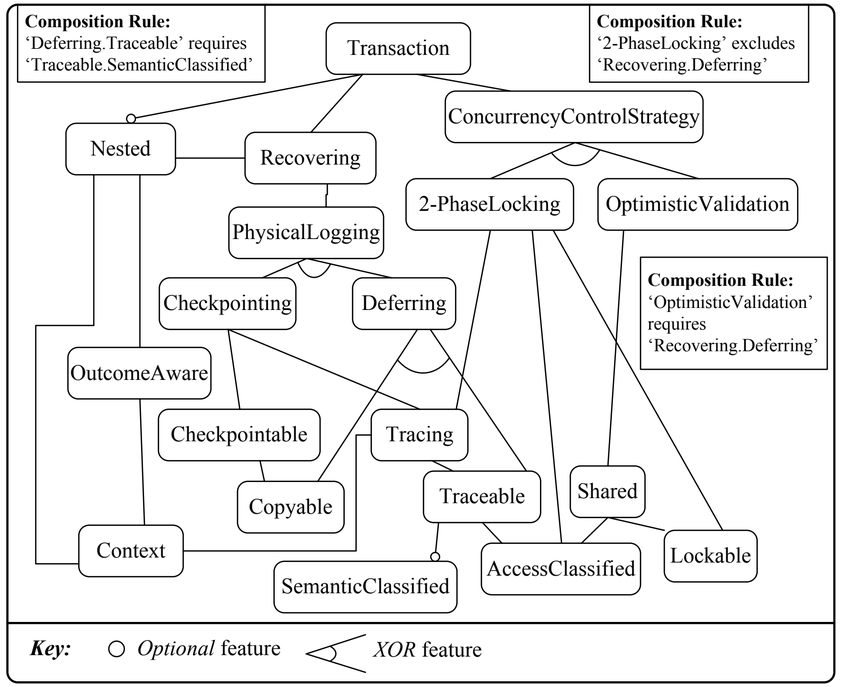

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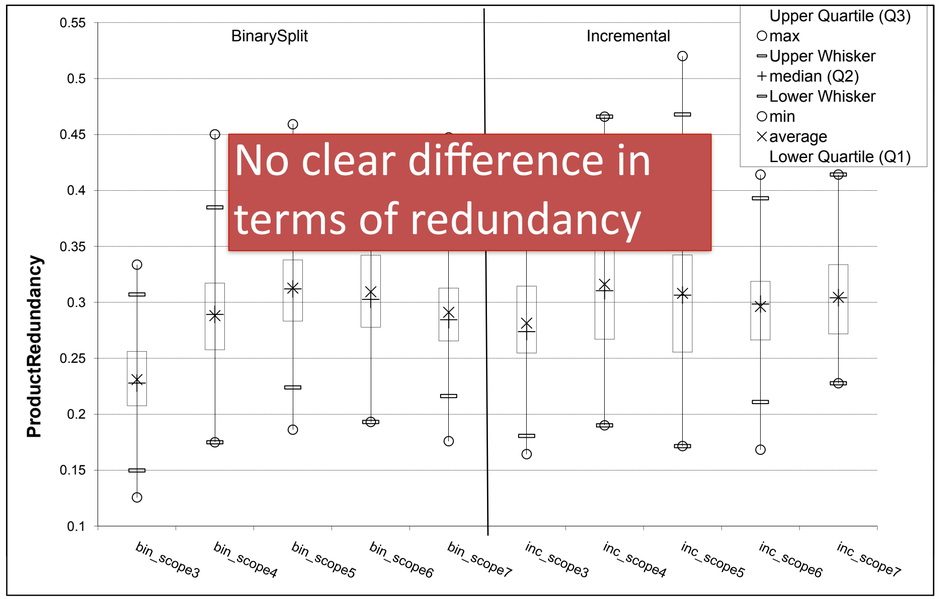

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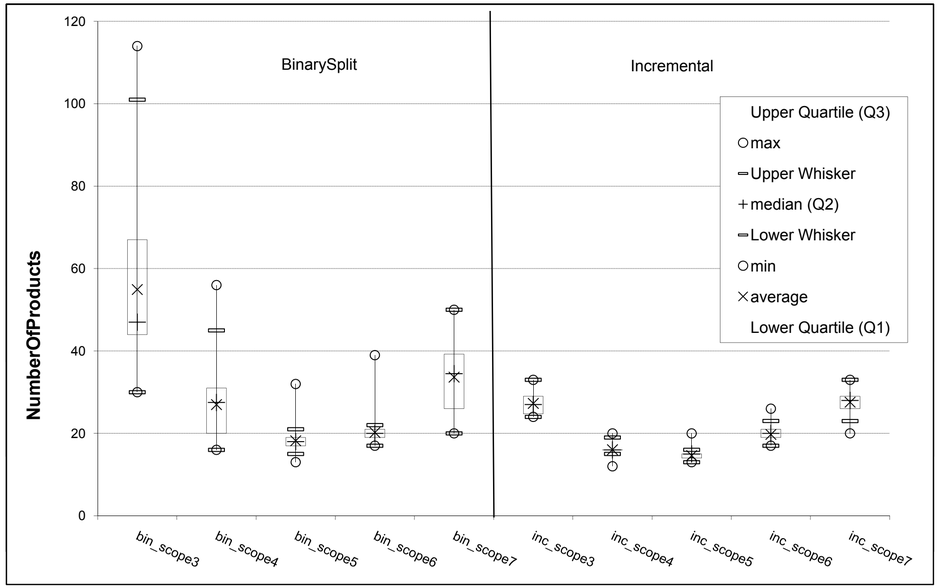

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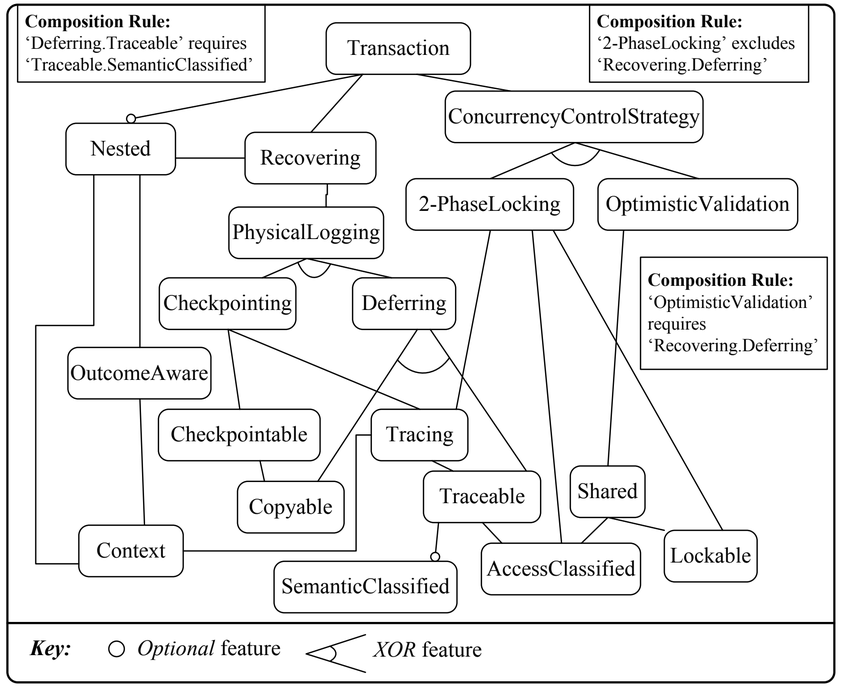

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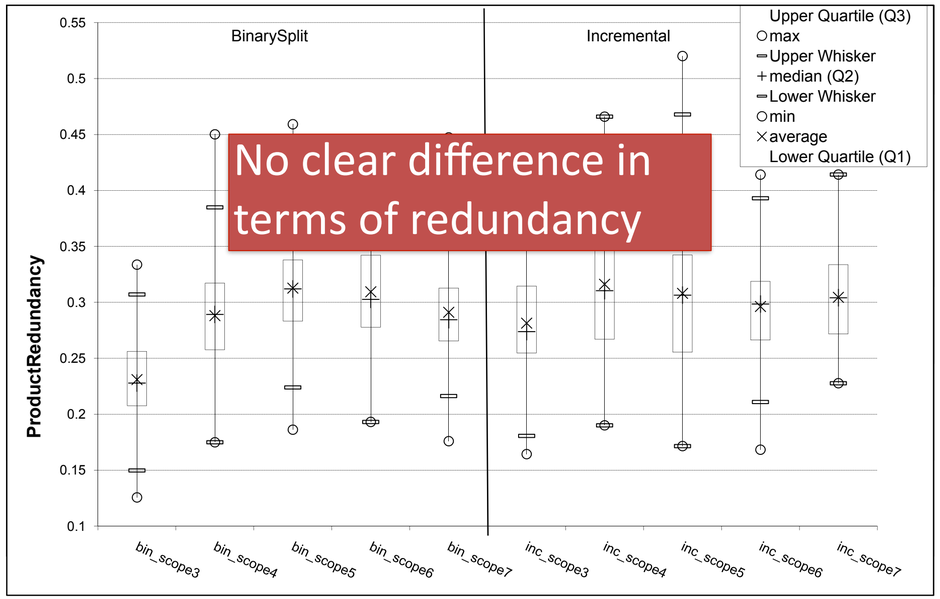

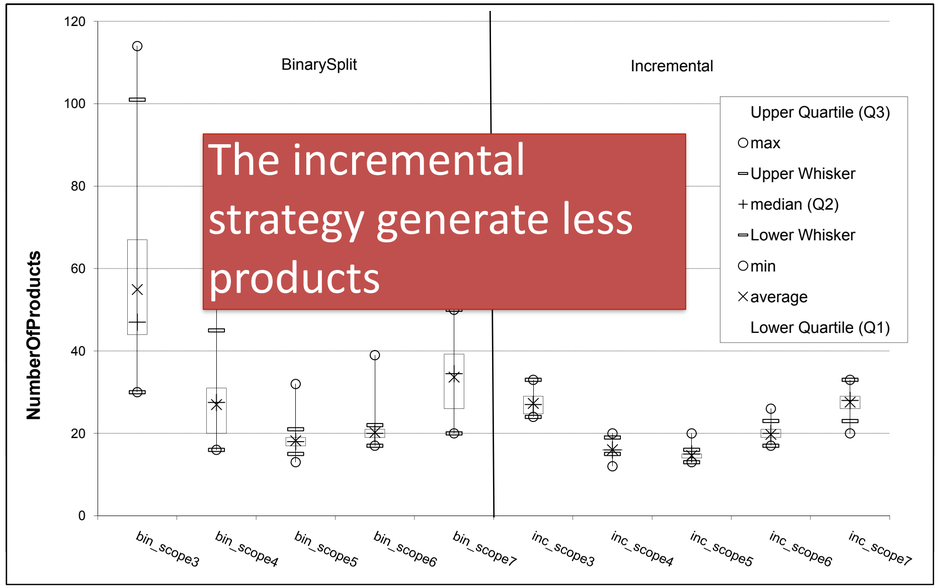

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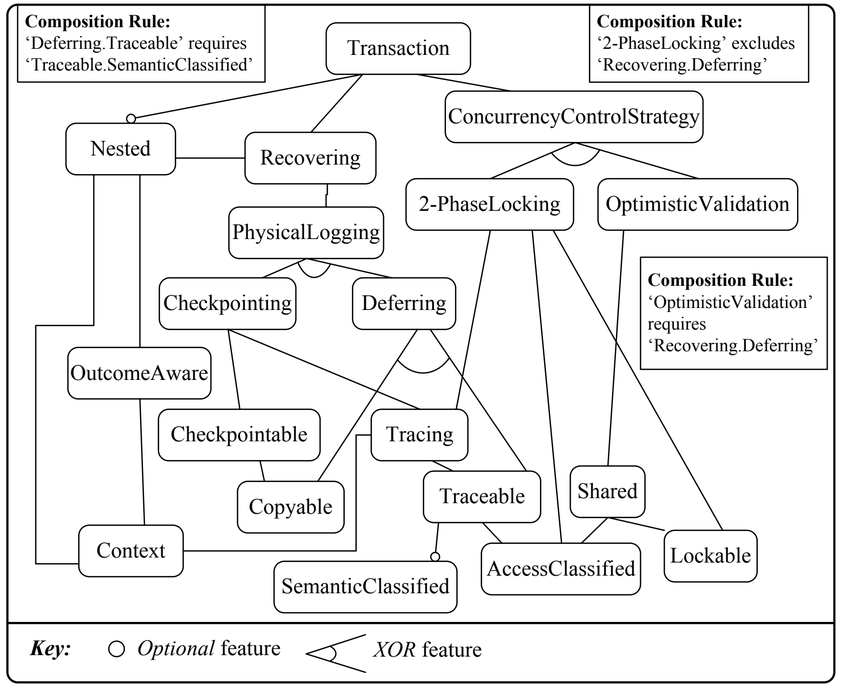

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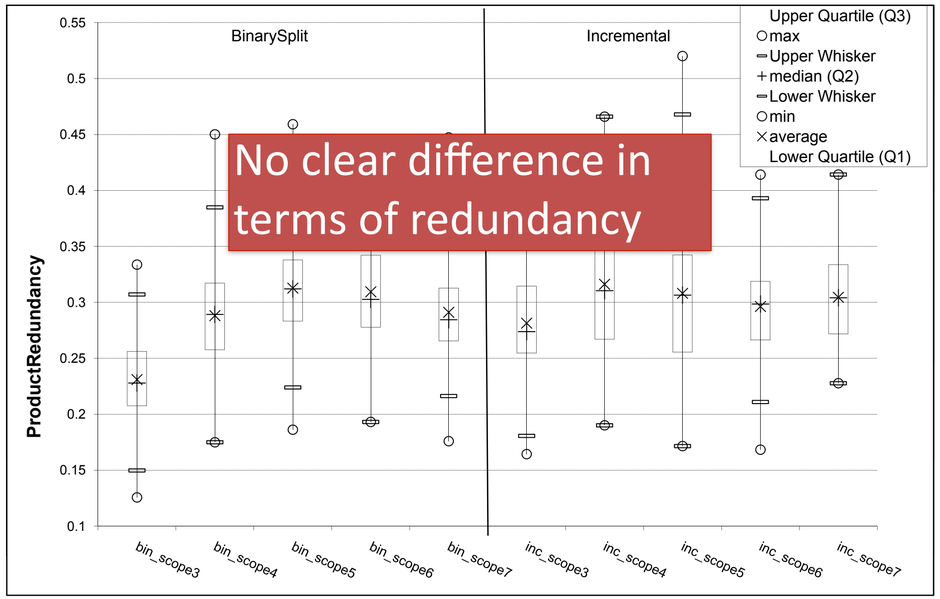

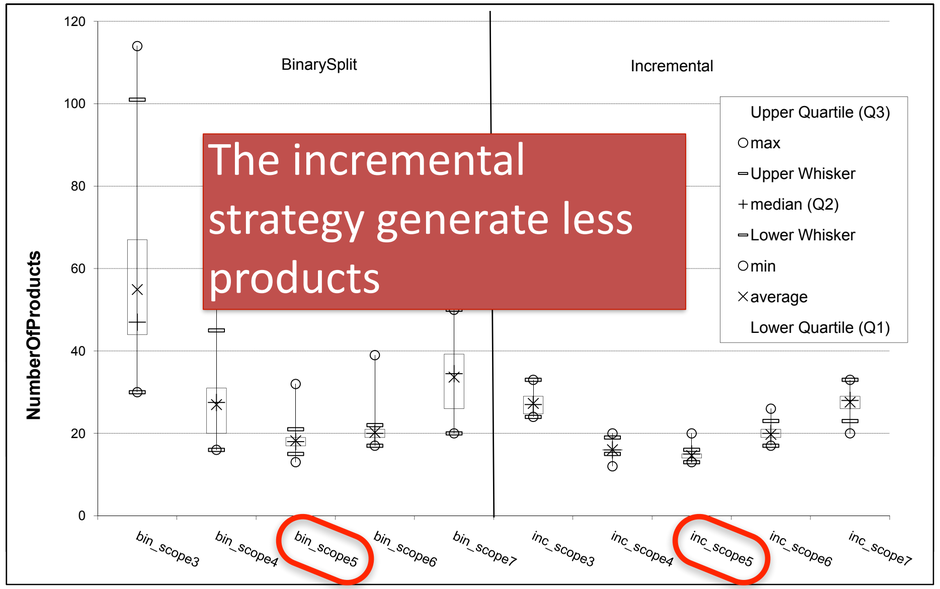

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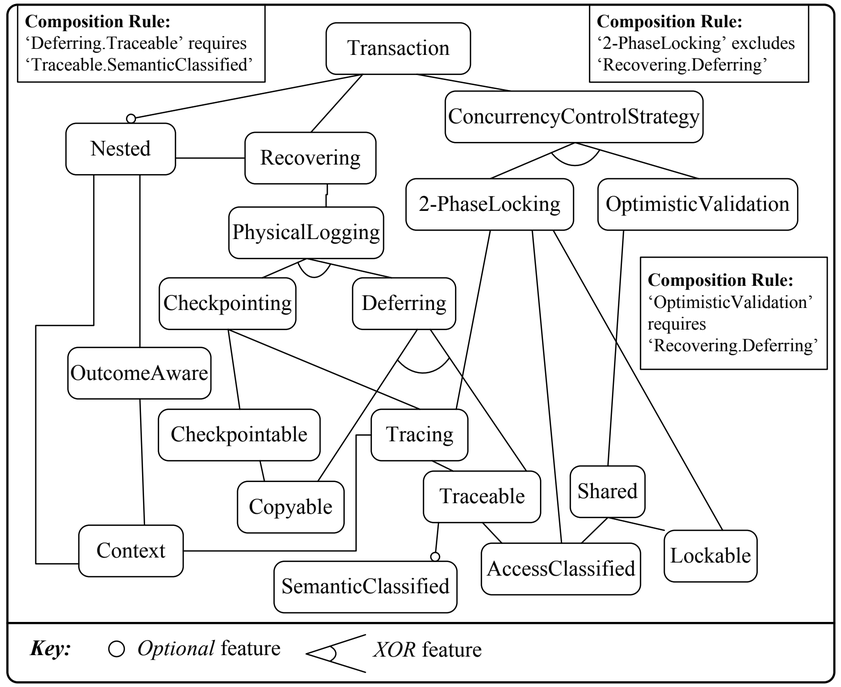

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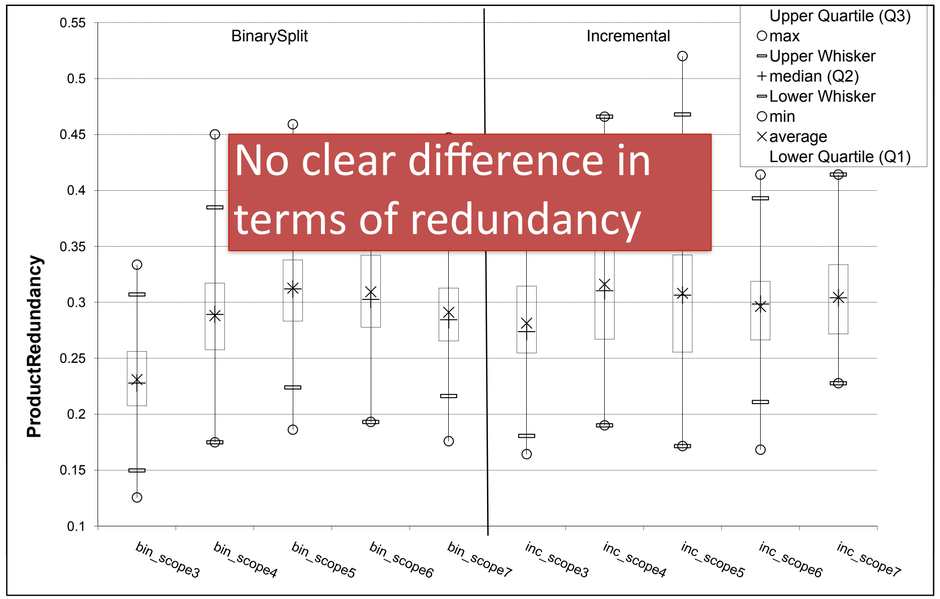

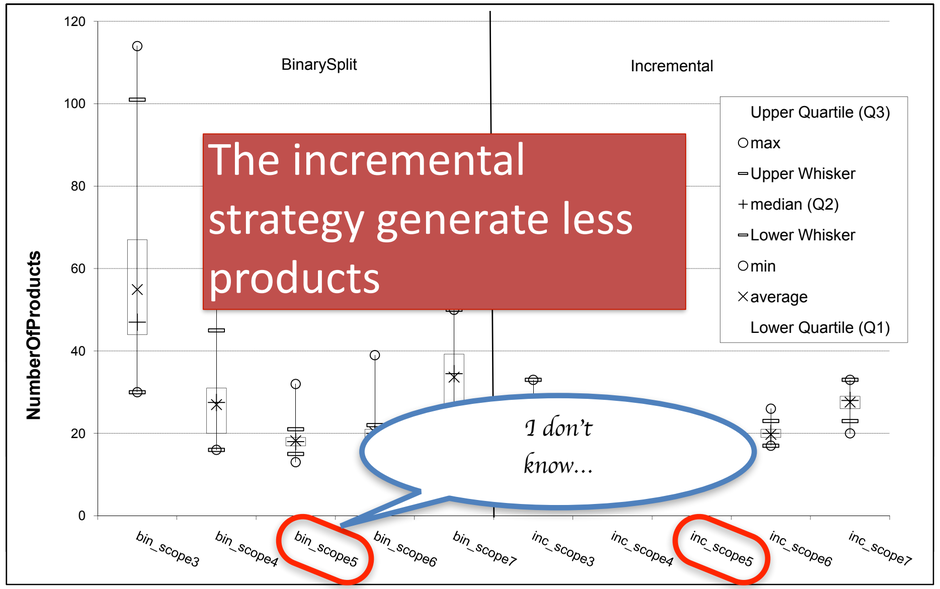

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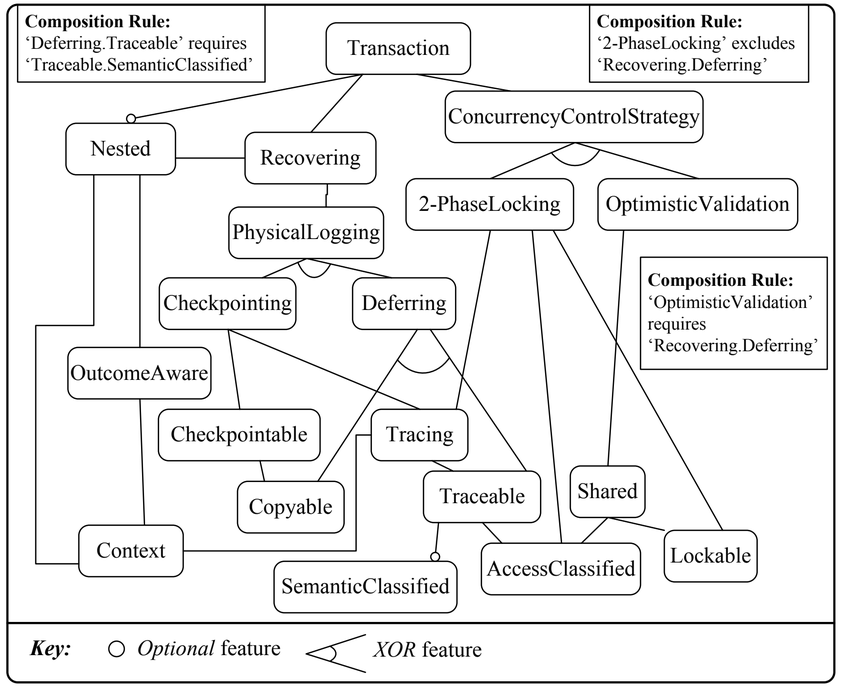

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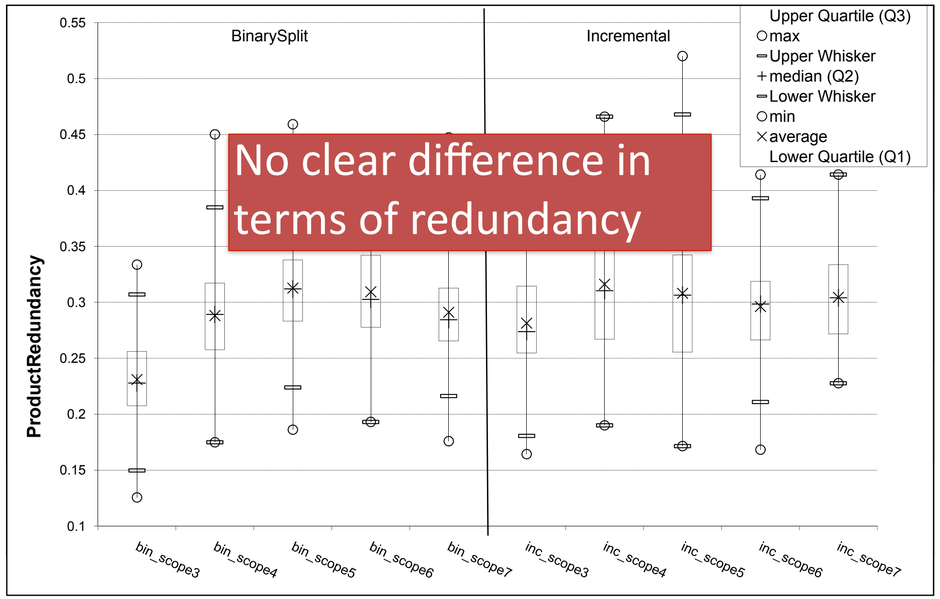

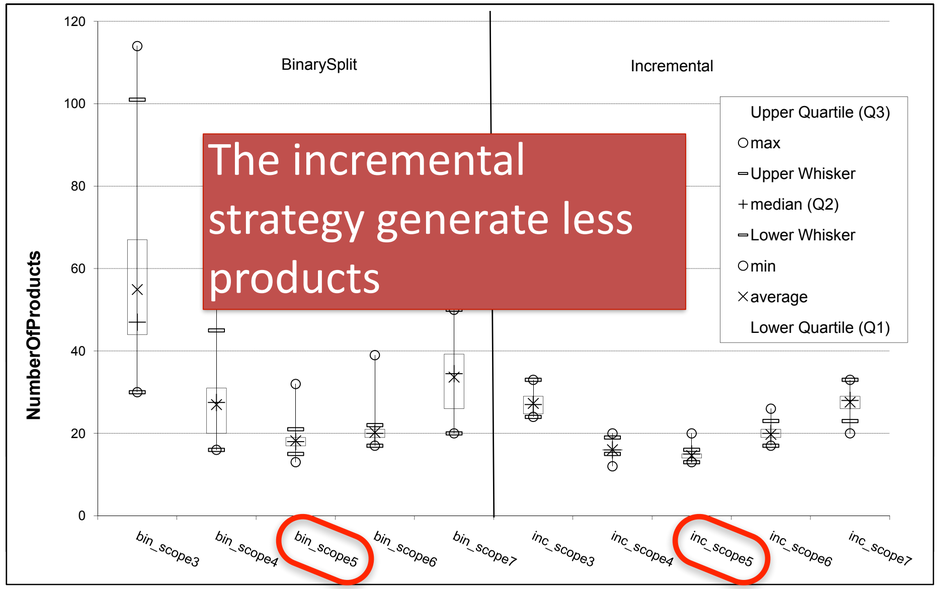

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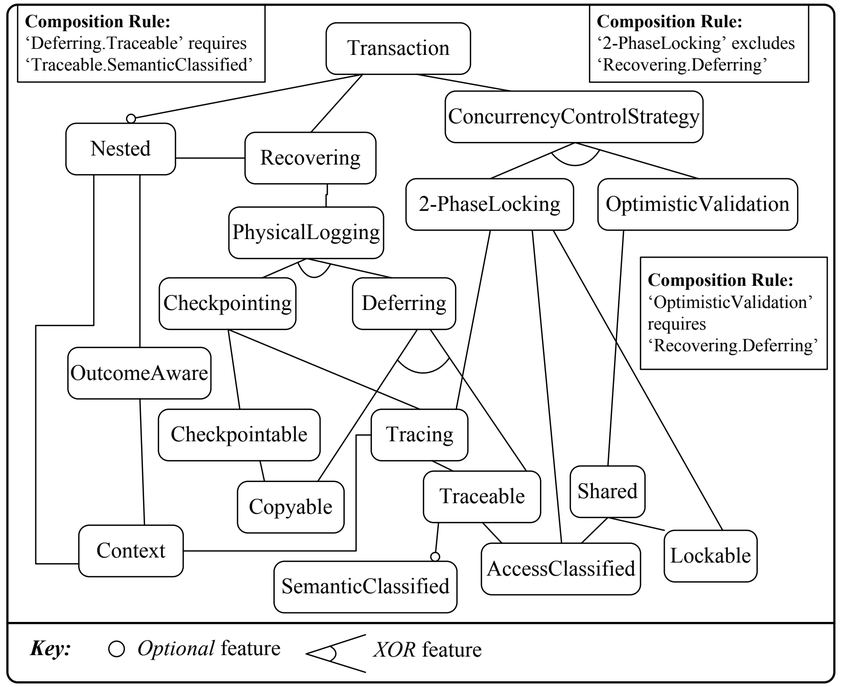

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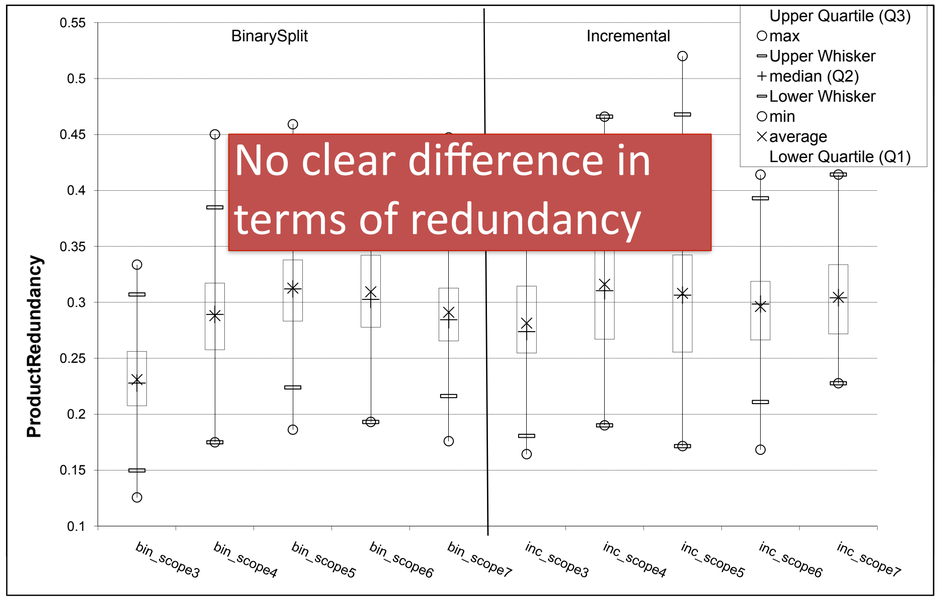

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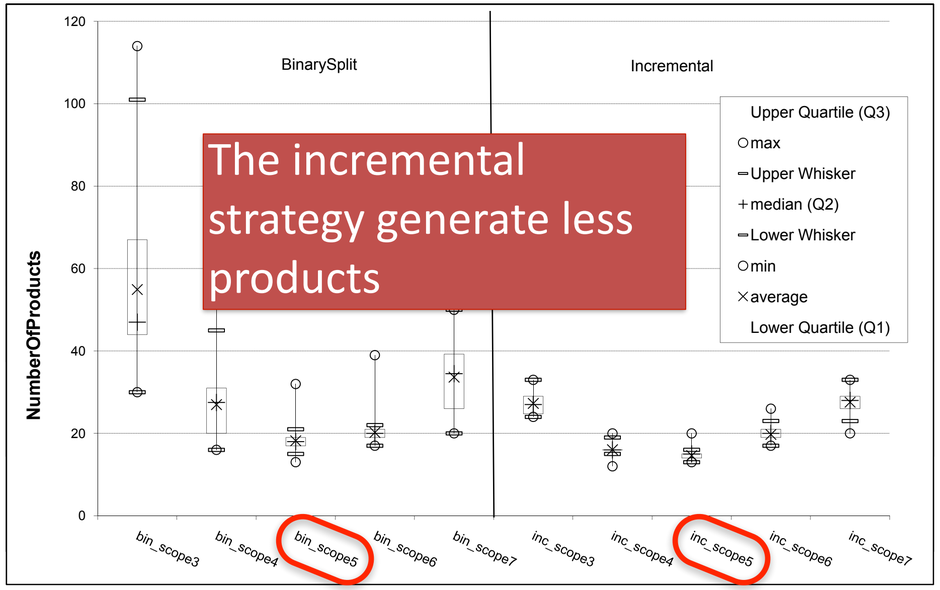
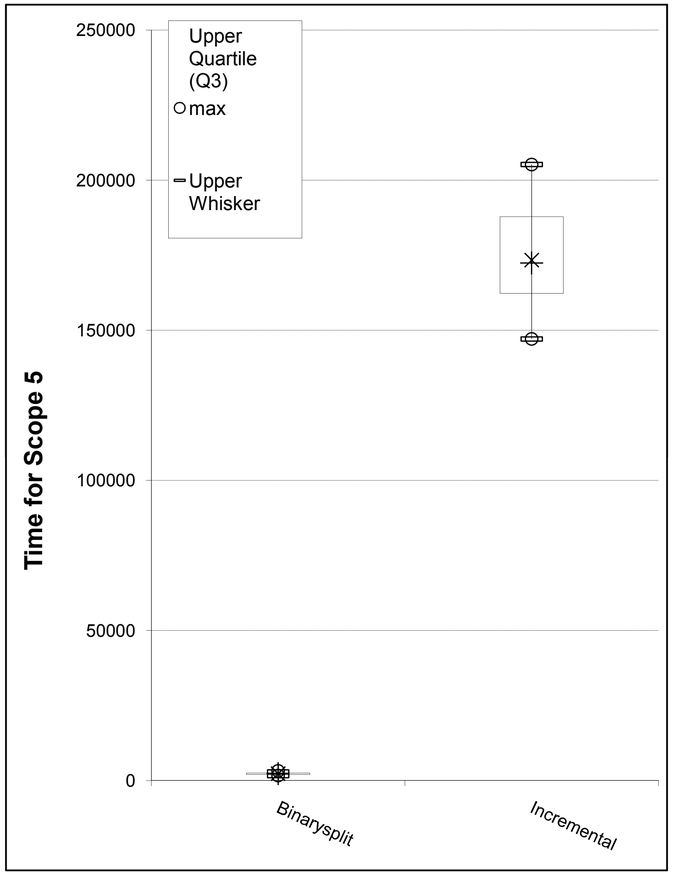


The incremental strategy generate less products



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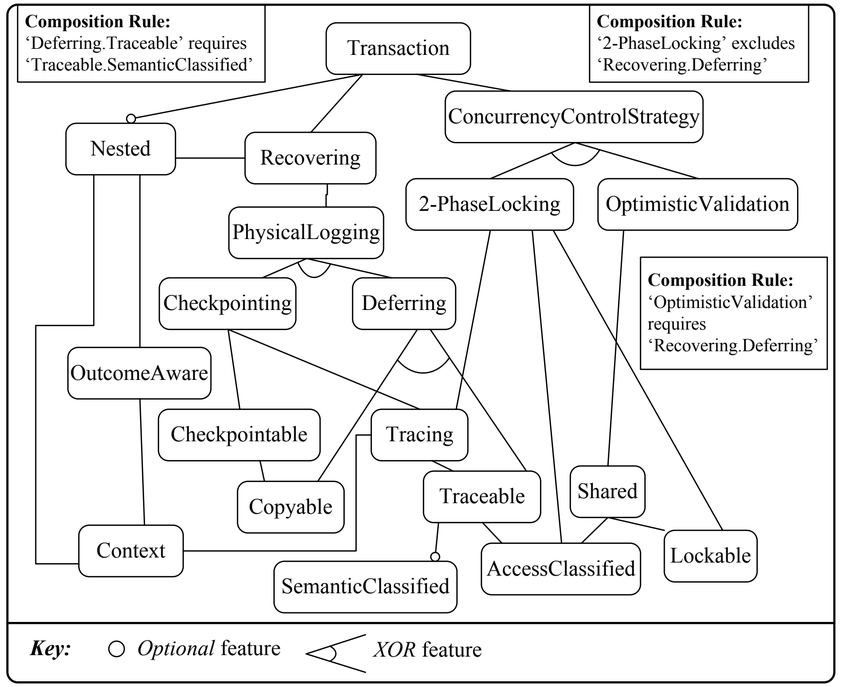

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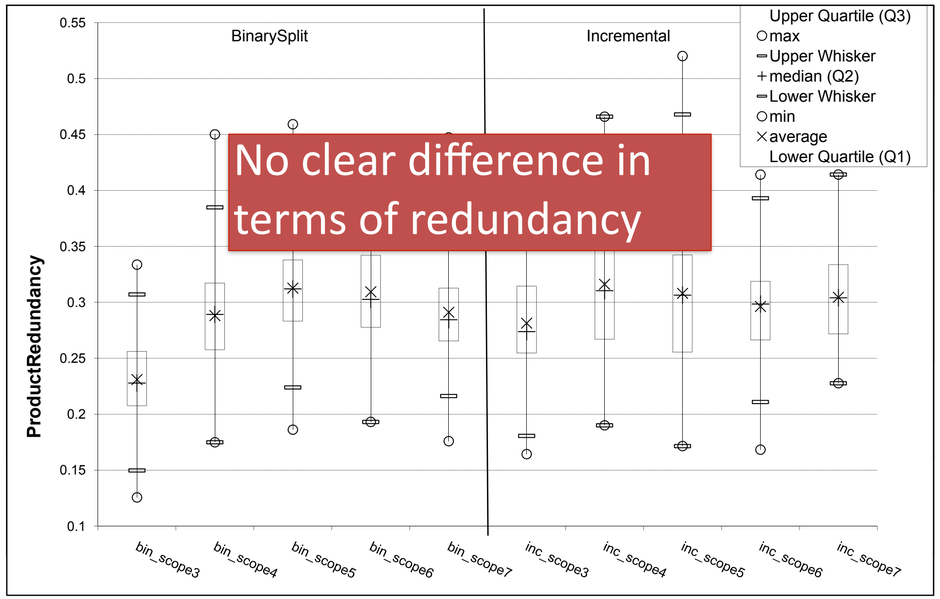

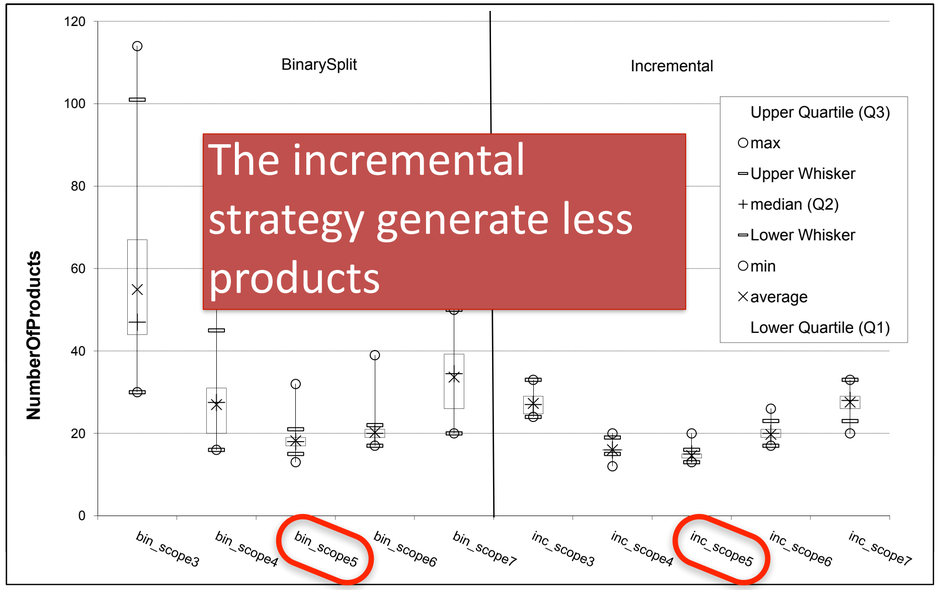

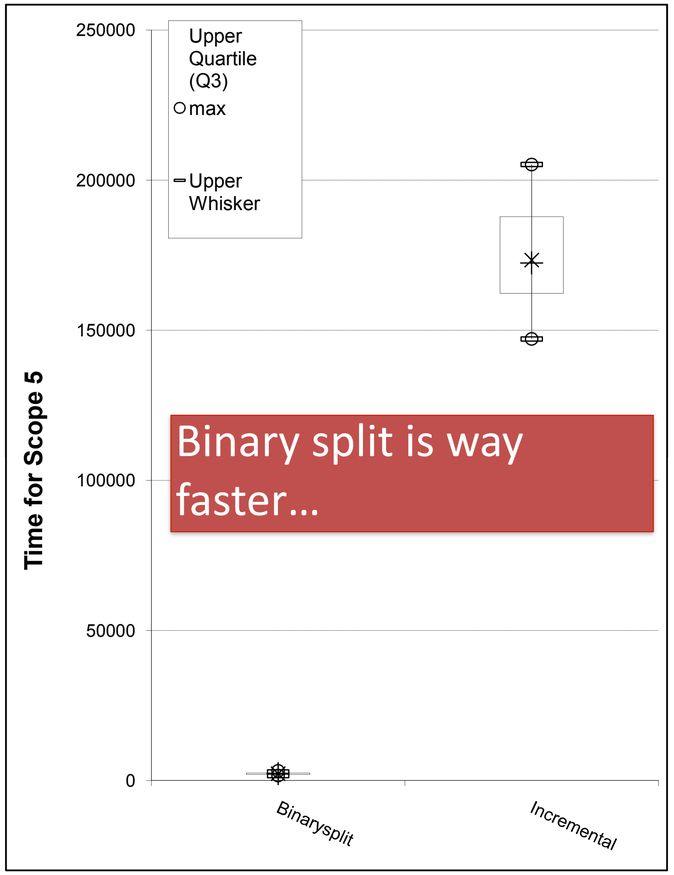

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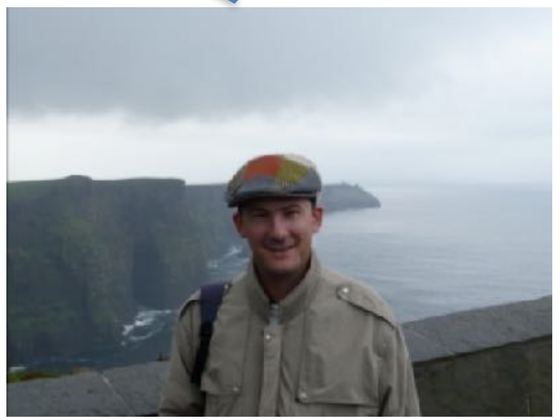

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3. Torlak, E., Jackson, D. (2007). Kodkod: A Relational Model Finder. In: Grumberg, O., Huth, M. (eds) Tools and Algorithms for the Construction and Analysis of Systems. TACAS 2007

CSP-Based Solution (Oster et al.)

- ***Pre-processing*** of feature models (flattening)
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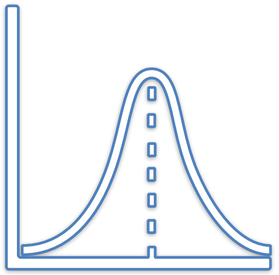

Improved metrics for ***similarity*** (Jaccard Distance)
Previous metrics: Test generation time, test suite size, …

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Sometimes you get defeated by a dragon…

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Table 1 Execution Times for Pairwise Generation on Feature Models. Key: CP = Cell Phone, SH = Smart Home, AG= Arcade Game, MT= Model Transformation, ES= Electronic Shopping

	CP	**SH**	**AG**	**MT**	**ES**
Features	19	35	61	88	287
Possible Products	61	1048576	$3.3 * 10^9$	$1.65 * 10^{13}$	$2.26 * 10^{49}$
Cross-Tree Constraints (%)	26	0	55	0	11
CSP-Dedicated (ms)	0	0	32	46	797
BinarySplit (ms)	11812	11457	33954	$>$ 32400000	$>$ 32400000
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Table 5 Test Suites Sizes Obtained for 3-wise Generation. Key: CP = Cell Phone, SH = Smart Home, AG=Arcade Game, MT= Model Transformation, ES= Electronic Shopping

	CP	SH	AG	MT	ES
CSP-Dedicated	23	61	257	643	841
BinarySplit	207	N/A	N/A	N/A	N/A
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Table 6 Test Suite Size and Duplicates for the Cell Phone Feature Model (3-wise)

	Test Suite Size	Duplicates
CSP-Dedicated	23	0
BinarySplit	207	156
IncGrowth	133	88

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Software Qual J (2012) 20:605–643
DOI 10.1007/s11219-011-9160-9

Pairwise testing for software product lines: comparison of two approaches

Gilles Perrouin · Sebastian Oster · Sagar Sen · Jacques Klein · Benoit Baudry · Yves le Traon

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And you got a MIP award for that?

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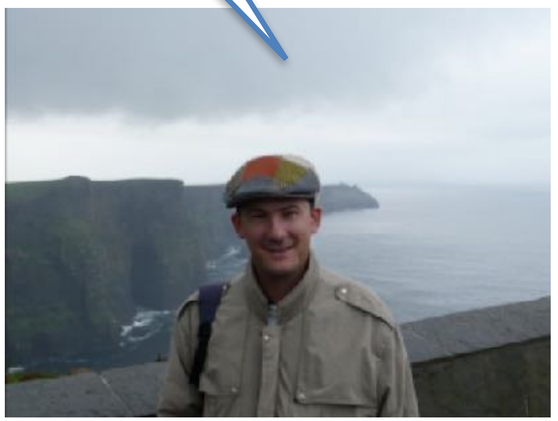
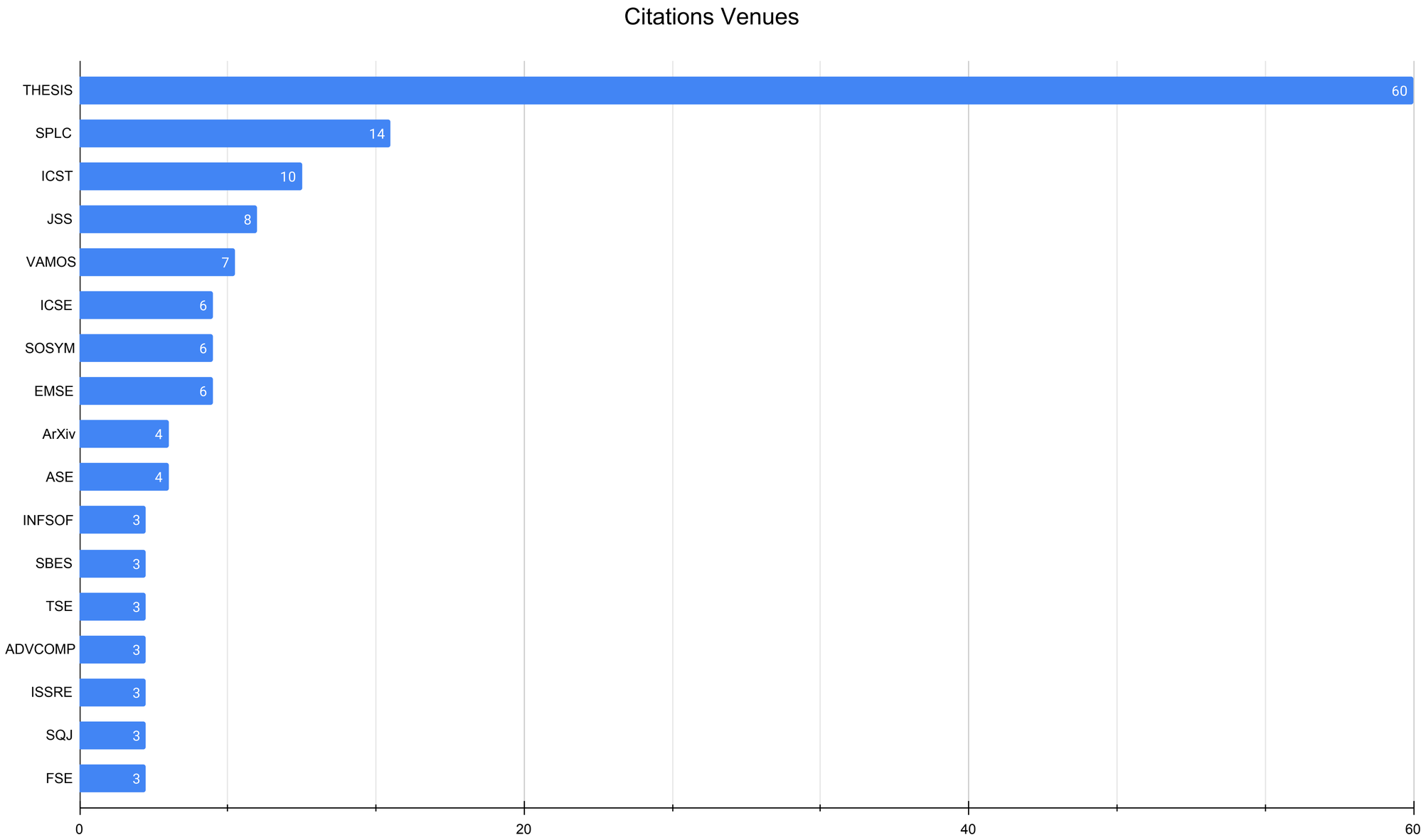
Not today Devil imposter syndrome…



Quantitative Impact



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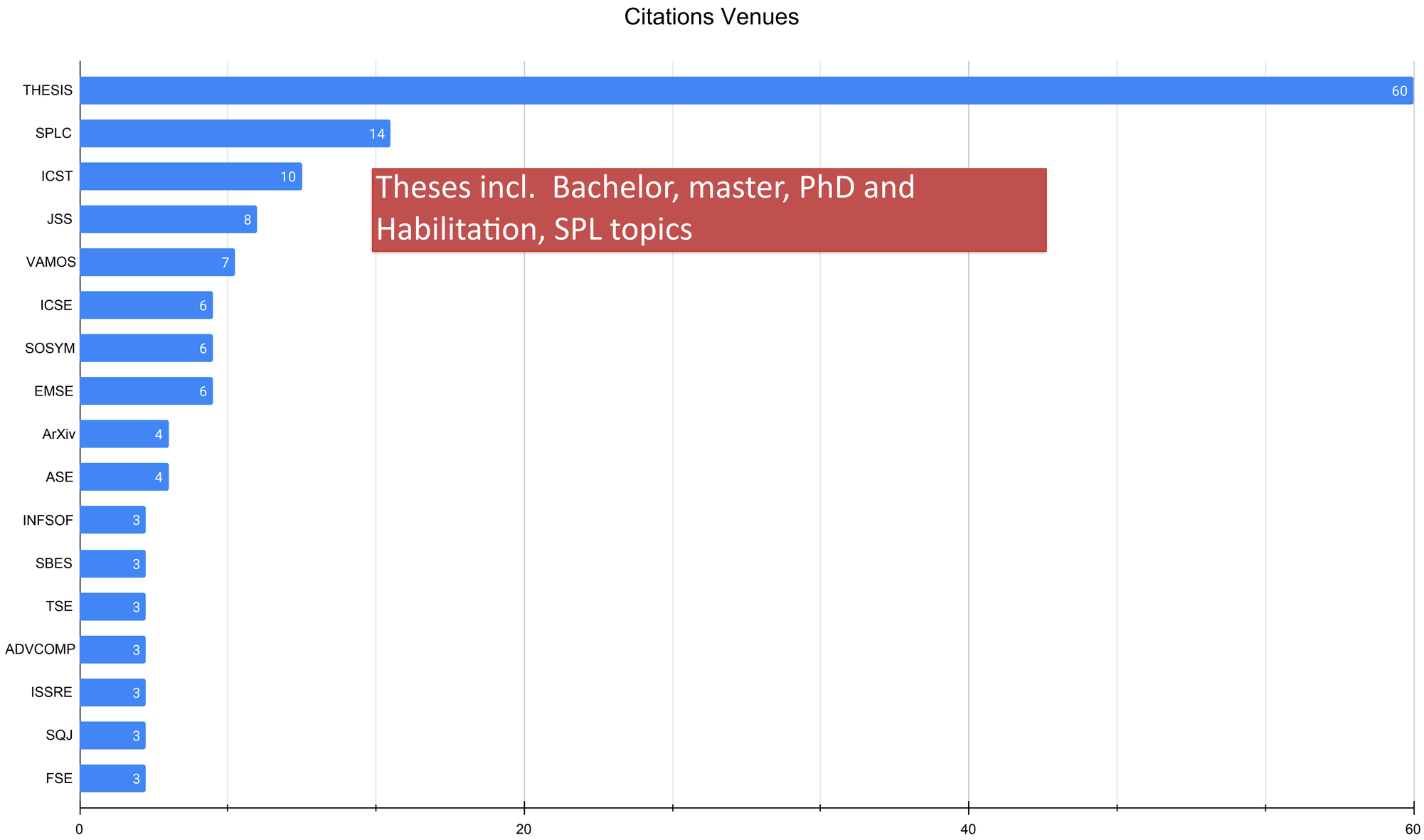

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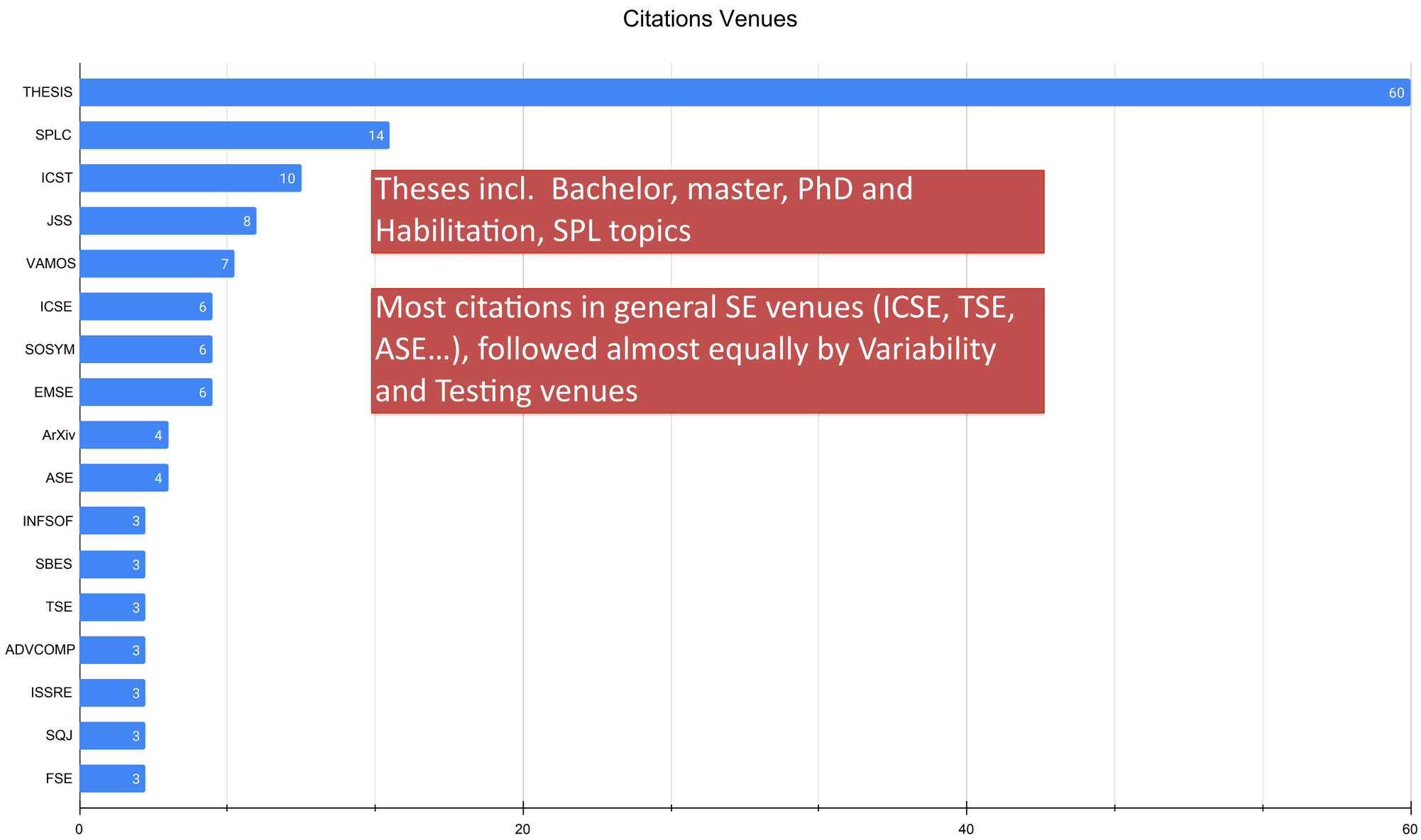

Theses incl. Bachelor, master, PhD and Habilitation, SPL topics

Most citations in general SE venues (ICSE, TSE, ASE…), followed almost equally by Variability and Testing venues

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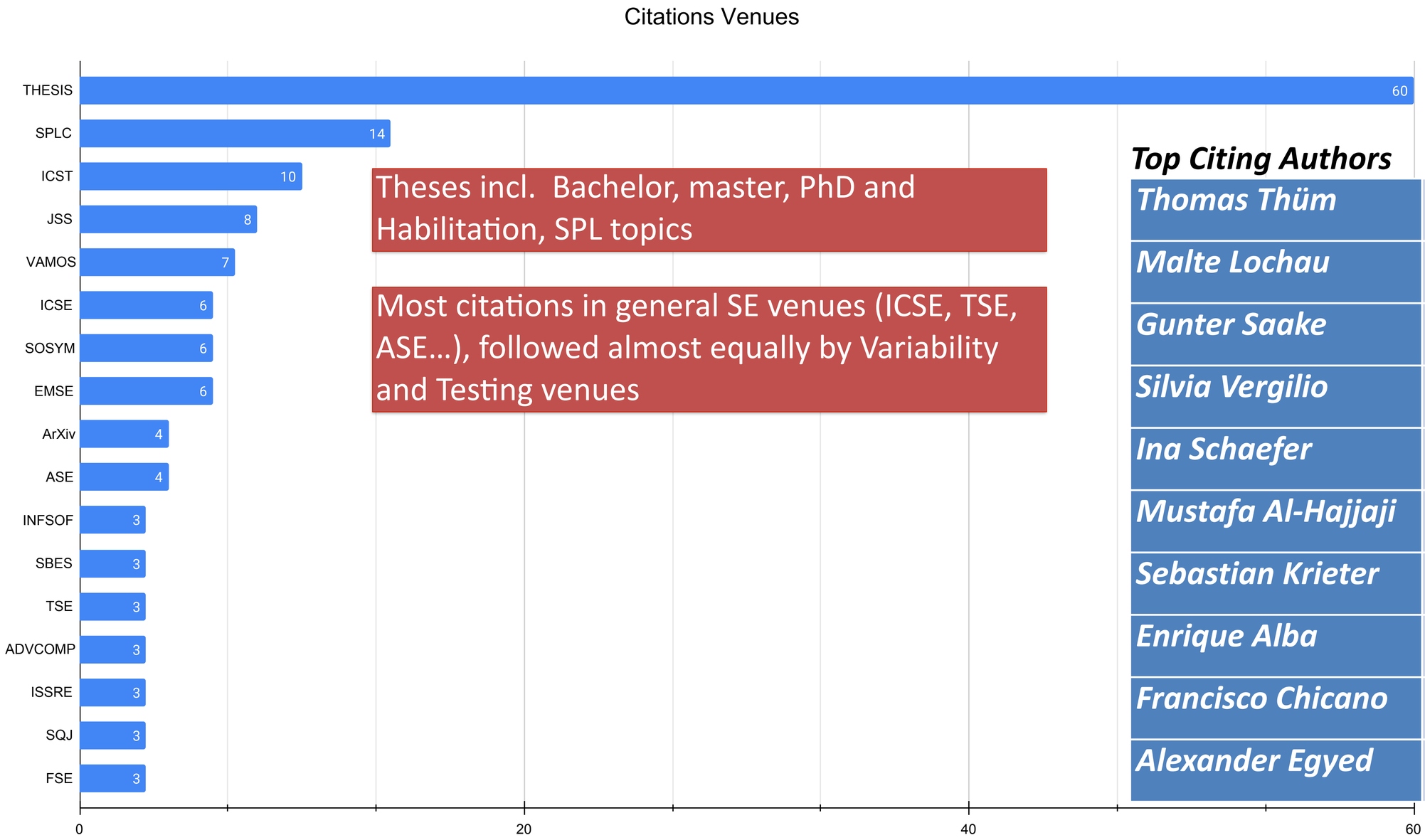

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Top Citing Authors

Thomas Thüm	***18***
Malte Lochau	***13***
Gunter Saake	***13***
Silvia Vergilio	***11***
Ina Schaefer	***10***
Mustafa Al-Hajjaji	***9***
Sebastian Krieter	***9***
Enrique Alba	***6***
Francisco Chicano	***6***
Alexander Egyed	***6***

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PACOGEN : Automatic Generation of Pairwise Test Configurations from Feature Models

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Email: {Aymeric.Hervieu,Benoit.Baudry}@inria.fr

Arnaud Gotlieb
Certus Software V&V Center
Simula Research Laboratory,
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Transformation into Prolog (ISSRE 2011)

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Properties of Realistic Feature Models Make Combinatorial Testing of Product Lines Feasible

Martin Fagereng Johansen[1,2], Øystein Haugen[1], and Franck Fleurey[1]

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Discussion on the problem's difficulty (MODELS 2011)

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The most important contribution however is the set of metrics we initially provided (and later formalized in the journal extension), notably the ***redundancy/similarity*** metric (adapted from the testing community)

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Christopher Henard, Mike Papadakis, *Member, IEEE*, Gilles Perrouin, *Member, IEEE*, Jacques Klein, *Member, IEEE*, Patrick Heymans, *Member, IEEE,* and Yves Le Traon, *Member, IEEE.*

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Similarity-Based Prioritization in Software Product-Line Testing

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University of Magdeburg
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TU Darmstadt
Germany

Gunter Saake
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SPLC 2014

IncLing: Efficient Product-Line Testing using Incremental Pairwise Sampling

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[1] University of Magdeburg, Germany, [2] TU Braunschweig, Germany, [3] TU Darmstadt, Germany

GPCE 2016

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TSE 2014

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Stability of Product-Line Sampling in Continuous Integration

Tobias Pett, TU Braunschweig, Germany
Sebastian Krieter, Hochschule Harz, Germany
Tobias Runge, TU Braunschweig, Germany
Thomas Thüm, Universität Ulm, Germany
Malte Lochau, Universität Siegen, Germany
Ina Schaefer, TU Braunschweig, Germany

VAMOS 2021

…integrate well with sampling algorithms…

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GPCE 2016

Personal Impact

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Opened me to testing…

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Ok bye…

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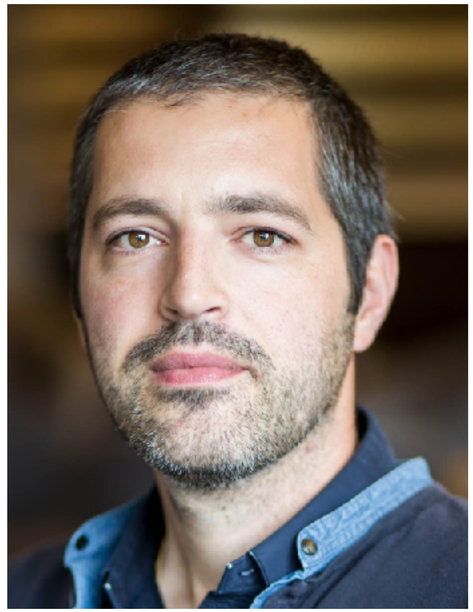

Thank you to the nominators…

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Mike Papadakis

Myra B. Cohen

Sergio Segura

Mathieu Acher

Sven Apel

Mark Harman

In every tale, some characters disappear too fast…

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Merci Papa

Yann Perrouin (1942-2024)

Conclusions

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Automated and Scalable T-wise Test Case Generation Strategies for Software Product Lines

Gilles Perrouin, Sagar Sen, Jacques Klein, Benoit Baudry, Yves Le Traon

SPLC 2024 MIP Award

Gilles Perrouin
gilles.perrouin@unamur.be
@GPerrouin

SPLC 2024, Luxembourg, September 5

PReCISE Namur Digital Institute NADI

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UNIVERSITÉ DE NAMUR

14 years later: From T-wise to sampling

14 years later: From T-wise to sampling

YASA: Yet Another Sampling Algorithm

Sebastian Krieter
University of Magdeburg
Magdeburg, Germany
Harz University of Applied Sciences
Wernigerode, Germany

Thomas Thüm
University of Ulm
Ulm, Germany

Sandro Schulze
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Magdeburg, Germany

Gunter Saake
University of Magdeburg
Magdeburg, Germany

Thomas Leich
Harz University of Applied Sciences
Wernigerode, Germany

VAMOS 2020

An Algorithm for Generating t-wise Covering Arrays from Large Feature Models

Martin Fagereng Johansen[1,2], Øystein Haugen[1] and Franck Fleurey[1]
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14 years later: From T-wise to sampling

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Magdeb…

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Optimized *t*-wise approaches

VAMOS 2020

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Optimized *t*-wise approaches

VAMOS 2020

An Algorithm for Generating t-wise Coverin[illegible]rays from Large Feature Models

Martin Fagereng Johansen[1,2], Øystein [illegible] and Franck Fleurey[1]
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Optimized *t*-wise approaches

SPLC 2012

MulTi-Wise Sampling: Trading Uniform T-Wise Feature Interaction Coverage for Smaller Samples

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SPLC 2024

14 years later: From T-wise to sampling

YASA: Yet Another Sampling Alg[illegible]

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Optimized *t*-wise approaches

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Mixed *t*-wise approaches

SPLC 2024

A Comparison of 10 Sampling Algorithms for Configurable Systems

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Sven Apel
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ICSE 2016

Test them all, is it worth it? Assessing configuration sampling on the JHipster Web development stack

Axel Halin[1] · Alexandre Nuttinck[2] · Mathieu Acher[3] · Xavier Devroey[4] · Gilles Perrouin[5] · Benoit Baudry[6]

EMSE 2019

Collecting Feature Models from the Literature: A Comprehensive Dataset for Benchmarking

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Vincenzo Francesco Brancaccio
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SPLC 2024

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SPLC 2024

Comparative Studies & Benchmarks

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SPLC 2024

Machine Learning Testing: Survey, Landscapes and Horizons

Jie M. Zhang*, Mark Harman, Lei Ma, Yang Liu

TSE 2022

An empirical investigation of organic software product lines

Mikaela Cashman[1,2] · Justin Firestone[3] · Myra B. Cohen[1] · Thammasak Thianniwet[4] · Wei Niu[5]

EMSE 2021

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SPLC 2024

Novel application areas (beyond SPLs)

Machine Learning Testing:
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TSE 2022

An empirical investigation of organic software product lines

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EMSE 2021

Answering the gate's keeper…

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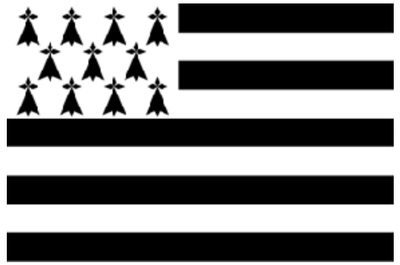

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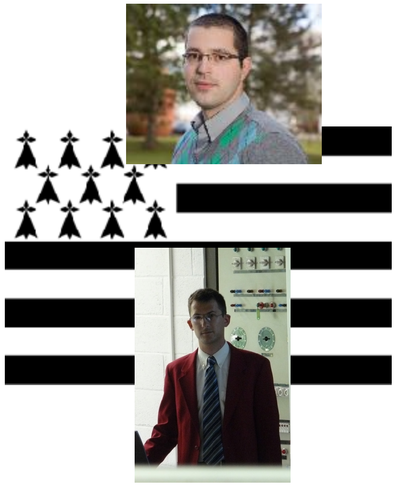

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Diversity-Centric Software Engineering

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DiverSE
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Reconciling Automation and Flexibility in Product Derivation

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SPLC'08

Answering the gate's keeper…

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- An Ecore metamodel based on Feature Diagrams' formalisation[1,2]

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2. Schobbens, P. Y., Heymans, P., Trigaux, J. C., & Bontemps, Y. G***eneric semantics of feature diagrams.*** Computer networks, 51(2), 456-479.

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- Leveraged a symmetric model composition engine to derive products' architectural models (classes)

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- An Ecore metamodel based on Feature Diagrams' formalisation[1,2]
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- Constraints defined by domain engineers to allow post-composition specialization (products not directly supported by the FD) while enforcing the SPL's invariants.

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