



Sampling Cardinality-Based Feature Models

Lukas Güthing, Mathis Weiß, Ina Schaefer, Malte Lochau

VaMoS 2024, Bern, Switzerland 8. Februar 2024



www.uni-siegen.de www.kit.edu

German Research Foundation

Motivating Example: Cloud-based Distributed Mobile Multiplayer Game



How to test a cloud-based SPL with...

- a variable number of users?
- a variable amount of resources?
- a variable composition of subsystems?

Source: https://www.nintendo.de/Spiele/Nintendo-Switch-Spiele/Everybody-1-2-Switch--2392520.html



Product-based Analysis?



Number of valid configurations 12



Cardinality-based Feature Models

Constructs of Cardinality-based Feature Models [1,2]





Cardinality-based Feature Models

Constructs of Cardinality-based Feature Models [1,2]





Product-based Analysis? – No, thank you...



Number of valid configurations 1.226



Product-based Analysis? – No, thank you... Infeasible



Number of valid configurations 3.108.084



Product-based Analysis? – No, thank you... Infeasible Impossible



Number of valid configurations ∞



Research Questions

(RQ1) How to define reasonable sampling criteria for CFMs?

(RQ2) How to perform automated sample generation for CFMs?



Cardinality-based Feature Models

Constructs of Cardinality-based Feature Models [1,2]





Configurations of Cardinality-based Feature Models



Instance-based configuration

"local" interpretation: invalid





Configurations of Cardinality-based Feature Models



"global" interpretation: valid





Research Challenges

RC 1:

Infinite configuration spaces in the unbounded case.

RC 2:

Excessively large configuration spaces in the bounded case.

RC 3: Non-convex configuration spaces.







(RQ1) How to define reasonable sampling criteria for CFMs?









(RQ1) How to define reasonable sampling criteria for CFMs?









(RQ1) How to define reasonable sampling criteria for CFMs?

RC 2: Excessively large configuration spaces: Use Multiset-based Configuration Semantics.



n = number of subtree compositions

k = number of subtree clones



RC 2: Excessively large configuration spaces: Use Multiset-based Configuration Semantics.



RC 3: Non-convex configuration spaces: Employ concepts from boundary interior tests.





RC 3: Non-convex configuration spaces: Employ concepts from boundary interior tests.





Team

One-Wise Sampling (RQ1): Sample for the Running Example



Multiplayer Game	Inter Team Communication	Broadcast	Unicast	Team	Player	Intra Team Commuication	WiFi	BT
1	1	0	1	2	2	1	0	2
1	1	1	0	4	4	1	2	2
1	1	1	0	8	64	1	0	8
1	1	0	1	8	64	1	8	0



Automated Sample Generation for CFMs (RQ2):



Future Work

Develop fully-fledged tool support for:

- Modelling CFMs
- Sampling CFMs
- Handling interval gaps

Build upon the proposed one-wise sample criterion:

• Pairwise / k-wise sample criteria

Overcome the lack of example models:

• Conduct case studies



Sampling Cardinality-Based Feature Models



- Impose finite bounds
- Make interval gaps explicit



- Use the global interpretations of CTCs
- Sample multiset-based instances



Employ concepts from boundary interior tests:

26

- Sample global boundaries
- Sample around gaps

References and Acknowledgments

[1]	Czarnecki, Krzysztof, and Chang Hwan Peter Kim. "Cardinality-based feature modeling and constraints: A progress report." International Workshop on Software Factories. ACM San Diego, California, USA, 2005.
[2]	Quinton, Clément, Daniel Romero, and Laurence Duchien. "Cardinality-based feature models with constraints: a pragmatic approach." Proceedings of the 17th International Software Product Line Conference. 2013.
[3]	Williams, H. Paul. "Model building in mathematical programming." John Wiley & Sons, 2013.
[4]	Weckesser, Markus, et al. "Mind the gap! Automated anomaly detection for potentially unbounded cardinality- based feature models." Fundamental Approaches to Software Engineering: 19th International Conference, FASE 2016, Eindhoven, The Netherlands, April 2–8, 2016, Proceedings 19. Springer Berlin Heidelberg, 2016.
[5]	Juodisius, Paulius, et al. "Clafer: Lightweight modeling of structure, behaviour, and variability." <i>arXiv preprint arXiv:1807.08576</i> (2018).
[6]	Schnabel, Thomas, et al. "Cardygan: Tool support for cardinality-based feature models." <i>Proceedings of the 10th International Workshop on Variability Modelling of Software-Intensive Systems</i> . 2016.
[7]	Howden, William E. "Methodology for the generation of program test data." <i>IEEE Transactions on computers</i> 100.5 (1975): 554-560.

This work has been funded by the German Research Foundation within the project Co-InCyTe.



