

Reengineering Software Product Variants into Software Product Line: REVPLINE Approach

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REVPLINE Approach

1.1 Abstract

In order to migrate software product variants that are considered similar into a Software Product Line (SPL), it is essential to identify the mandatory and optional features between the product variants. To exploit existing software variants and build a SPL, a feature model of this SPL must be built as a first step. To do so, it is necessary to mine optional and mandatory features from the source code of the software variants. Thus, we propose in this book, a new approach to mine features and feature models from the object-oriented source code of a set of software variants, based on Formal Concept Analysis and Latent Semantic Indexing. To validate our approach, we applied it to ArgoUML and Mobile media case studies. The results of this evaluation validate the relevance and the performance of our proposal as most of the features were correctly identified.

Keywords: REVPLINE approach, Reengineering, Feature mining, Feature Model, Software Product Line Engineering, Software product variants, Structural similarity, Lexical similarity, Formal Concept Analysis, Latent Semantic Indexing, Code dependencies.

1.2 Introduction

Similarly to car manufacturers who propose a full range of cars with common characteristics and numerous variants and options, software development may cater to various needs and propose as a result a software family instead of one single product. Such software family is called a *software product line* (SPL).

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1.3 Conclusion and Perspectives

In this book, we proposed an approach based on FCA and LSI to mine features and feature model from the object-oriented source code of software product variants. We have implemented our approach and evaluated its produced results on two case studies. The results of this evaluation validate the relevance and the performance of our proposal as most of the features were correctly identified.

The threat to the validity of our approach is that developers might not use the same vocabularies to name OBEs across software product variants. This means that lexical similarity may be not reliable (or should be improved with other techniques) in all cases to identify common and variable features.

Furthermore, there is a limitation to using FCA as a clustering technique. FCA deals with binary formal context $(1, 0)$. When we transform the (numerical) cosine similarity matrices into (binary) formal contexts, we use a threshold. So if the similarity value between query and document is greater than or equal

to 0.70, the two documents are considered similar. By contrast, if the similarity value is less than the threshold (*i.e.*, 0.69) the two documents are considered not similar. FCA deals with discrete values (0, 1). This affects the quality of the result, where the similarity value 0.99 is equal to 0.70 and 0.69 is equal to 0.

In the future, we plan to identify the junctions between feature implementations in an automatic way. We also plan to automatically propose feature names for the atomic blocks (*i.e.*, feature implementations). Finally, we plan to use the mined common and variable features and the lattices to automate the building of the studied software family’s feature model with its constraints.

In this book, we proposed an approach to extract features and feature model from software variants configurations. As a perspective of this work, we plan to develop a framework that enables us to derive the requested software based on the extracted feature model and the core asset that extracted by REVPLINE approach (*cf.* Figure 1.1).

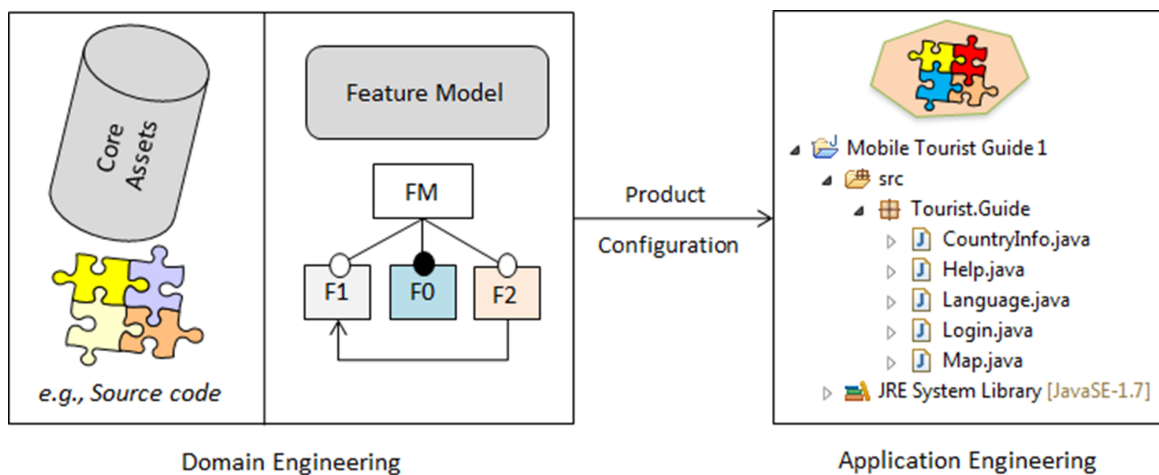


Figure 1.1: Extraction of a product by selecting its features from FM.

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Bibliography

- [1] P. Clements and L. Northrop, *Software Product Lines: Practices and Patterns*, ser. The SEI series in software engineering. Addison Wesley Professional, 2002. [Online]. Available: <http://books.google.fr/books?id=tHGfQgAACAAJ>
- [2] L. P. Tizzei, M. Dias, C. M. F. Rubira, A. Garcia, and J. Lee, “Components meet aspects: Assessing design stability of a software product line,” *Inf. Softw. Technol.*, vol. 53, no. 2, pp. 121–136, Feb. 2011. [Online]. Available: <http://dx.doi.org/10.1016/j.infsof.2010.08.007>
- [3] Y. Xue, Z. Xing, and S. Jarzabek, “Feature location in a collection of product variants,” in *Proceedings of the 2012 19th Working Conference on Reverse Engineering*, ser. WCRE '12. Washington, DC, USA: IEEE Computer Society, 2012, pp. 145–154. [Online]. Available: <http://dx.doi.org/10.1109/WCRE.2012.24>
- [4] T. Ziadi, L. Frias, M. A. A. da Silva, and M. Ziane, “Feature identification from the source code of product variants,” in *Proceedings of the 2012 16th European Conference on Software Maintenance and Reengineering*, ser. CSMR '12. Washington, DC, USA: IEEE Computer Society, 2012, pp. 417–422. [Online]. Available: <http://dx.doi.org/10.1109/CSMR.2012.52>
- [5] S. She, R. Lotufo, T. Berger, A. Wąsowski, and K. Czarnecki, “Reverse engineering feature models,” in *Proceedings of the 33rd*

- International Conference on Software Engineering*, ser. ICSE '11. New York, NY, USA: ACM, 2011, pp. 461–470. [Online]. Available: <http://doi.acm.org/10.1145/1985793.1985856>
- [6] C. Dietrich, R. Tartler, W. Schröder-Preikschat, and D. Lohmann, “A robust approach for variability extraction from the linux build system,” in *Proceedings of the 16th International Software Product Line Conference - Volume 1*, ser. SPLC '12. New York, NY, USA: ACM, 2012, pp. 21–30. [Online]. Available: <http://doi.acm.org/10.1145/2362536.2362544>
- [7] M. Acher, B. Baudry, P. Heymans, A. Cleve, and J.-L. Hainaut, “Support for reverse engineering and maintaining feature models,” in *Proceedings of the Seventh International Workshop on Variability Modelling of Software-intensive Systems*, ser. VaMoS '13. New York, NY, USA: ACM, 2013, pp. 20:1–20:8. [Online]. Available: <http://doi.acm.org/10.1145/2430502.2430530>
- [8] K. Pohl, G. Böckle, and F. J. v. d. Linden, *Software Product Line Engineering: Foundations, Principles and Techniques*. Secaucus, NJ, USA: Springer-Verlag New York, Inc., 2005.
- [9] M. Acher, “Managing multiple feature models: Foundations, language, and applications,” Ph.D. dissertation, University of Nice Sophia Antipolis, Nice, France, sep. 2011.
- [10] I. Jacobson, M. Griss, and P. Jonsson, *Software reuse: architecture process and organization for business success*, ser. ACM Press books. ACM Press, 1997. [Online]. Available: <http://books.google.fr/books?id=wrFQAAAAMAAJ>
- [11] C. W. Krueger, “Software reuse,” *ACM Comput. Surv.*, vol. 24, no. 2,

pp. 131–183, Jun. 1992. [Online]. Available: <http://doi.acm.org/10.1145/130844.130856>

- [12] J. Pine, *Mass Customization: The New Frontier in Business Competition*. Harvard Business School Press, 1993. [Online]. Available: <http://books.google.fr/books?id=Seli55Gt-sEC>
- [13] S. Apel, D. Batory, C. Kästner, and G. Saake, “A development process for feature-oriented product lines,” in *Feature-Oriented Software Product Lines*. Springer Berlin Heidelberg, 2013, pp. 17–44. [Online]. Available: http://dx.doi.org/10.1007/978-3-642-37521-7_2
- [14] F. J. v. d. Linden, K. Schmid, and E. Rommes, *Software Product Lines in Action: The Best Industrial Practice in Product Line Engineering*. Secaucus, NJ, USA: Springer-Verlag New York, Inc., 2007.
- [15] K. Schmid and M. Verlage, “The economic impact of product line adoption and evolution,” *IEEE Softw.*, vol. 19, no. 4, pp. 50–57, Jul. 2002. [Online]. Available: <http://dx.doi.org/10.1109/MS.2002.1020287>
- [16] J. D. McGregor, L. M. Northrop, S. Jarrad, and K. Pohl, “Guest editors’ introduction: Initiating software product lines,” *IEEE Softw.*, vol. 19, no. 4, pp. 24–27, Jul. 2002. [Online]. Available: <http://dx.doi.org/10.1109/MS.2002.1020282>
- [17] L. Chen, M. Ali Babar, and N. Ali, “Variability management in software product lines: a systematic review,” in *Proceedings of the 13th International Software Product Line Conference*, ser. SPLC ’09. Pittsburgh, PA, USA: Carnegie Mellon University, 2009, pp. 81–90. [Online]. Available: <http://dl.acm.org.gate6.inist.fr/citation.cfm?id=1753235.1753247>
- [18] D. M. Weiss and C. T. R. Lai, *Software product-line engineering: a family-*

based software development process. Boston, MA, USA: Addison-Wesley Longman Publishing Co., Inc., 1999.

- [19] M. Svahnberg, J. van Gorp, and J. Bosch, “A taxonomy of variability realization techniques: Research articles,” *Softw. Pract. Exper.*, vol. 35, no. 8, pp. 705–754, Jul. 2005. [Online]. Available: <http://dx.doi.org/10.1002/spe.v35:8>
- [20] K.-C. Kang, *Feature-oriented Domain Analysis (FODA): Feasibility Study; Technical Report CMU/SEI-90-TR-21 - ESD-90-TR-222.* Software Engineering Inst., Carnegie Mellon Univ., 1990. [Online]. Available: <http://books.google.fr/books?id=yYi5PgAACAAJ>
- [21] K. C. Kang, S. Kim, J. Lee, K. Kim, E. Shin, and M. Huh, “Form: A feature-oriented reuse method with domain-specific reference architectures,” *Ann. Software Eng.*, vol. 5, pp. 143–168, 1998.
- [22] M. L. Griss, J. Favaro, and M. d. Alessandro, “Integrating feature modeling with the rseb,” in *Proceedings of the 5th International Conference on Software Reuse*, ser. ICSR '98. Washington, DC, USA: IEEE Computer Society, 1998, pp. 76–. [Online]. Available: <http://dl.acm.org/citation.cfm?id=551789.853486>
- [23] F. Bachmann and L. Bass, “Managing variability in software architectures,” *SIGSOFT Softw. Eng. Notes*, vol. 26, no. 3, pp. 126–132, May 2001. [Online]. Available: <http://doi.acm.org/10.1145/379377.375274>
- [24] G. Halmans and K. Pohl, “Communicating the variability of a software-product family to customers,” *Inform., Forsch. Entwickl.*, vol. 18, no. 3-4, pp. 113–131, 2004.
- [25] A. Metzger, P. Heymans, K. Pohl, P.-Y. Schobbens, and G. Saval, “Disambiguating the documentation of variability in software product lines:

A separation of concerns, formalization and automated analysis,” in *RE*, 2007, pp. 243–253.

- [26] K. Czarnecki and U. W. Eisenecker, *Generative programming: methods, tools, and applications*. New York, NY, USA: ACM Press/Addison-Wesley Publishing Co., 2000.
- [27] P. Zave and M. Jackson, “Four dark corners of requirements engineering,” *ACM Trans. Softw. Eng. Methodol.*, vol. 6, no. 1, pp. 1–30, Jan. 1997. [Online]. Available: <http://doi.acm.org/10.1145/237432.237434>
- [28] D. Batory, “Feature models, grammars, and propositional formulas,” in *Proceedings of the 9th international conference on Software Product Lines*, ser. SPLC’05. Berlin, Heidelberg: Springer-Verlag, 2005, pp. 7–20. [Online]. Available: http://dx.doi.org/10.1007/11554844_3
- [29] S. Apel and C. Kästner, “An overview of feature-oriented software development,” *Journal of Object Technology*, vol. 8, no. 5, pp. 49–84, July/August 2009, refereed Column. [Online]. Available: http://www.jot.fm/issues/issue_2009_07/column5/index.html
- [30] J. Bosch, *Design and use of software architectures: adopting and evolving a product-line approach*. New York, NY, USA: ACM Press/Addison-Wesley Publishing Co., 2000.
- [31] K. Chen, W. Zhang, H. Zhao, and H. Mei, “An approach to constructing feature models based on requirements clustering,” in *Proceedings of the 13th IEEE International Conference on Requirements Engineering*, ser. RE ’05. Washington, DC, USA: IEEE Computer Society, 2005, pp. 31–40. [Online]. Available: <http://dx.doi.org/10.1109/RE.2005.9>
- [32] D. Batory, J. Liu, and J. N. Sarvela, “Refinements and multi-dimensional separation of concerns,” *SIGSOFT Softw. Eng. Notes*,

vol. 28, no. 5, pp. 48–57, Sep. 2003. [Online]. Available: <http://doi.acm.org/10.1145/949952.940079>

- [33] A. Classen, P. Heymans, and P.-Y. Schobbens, “What’s in a feature: a requirements engineering perspective,” in *Proceedings of the Theory and practice of software, 11th international conference on Fundamental approaches to software engineering*, ser. FASE’08/ETAPS’08. Berlin, Heidelberg: Springer-Verlag, 2008, pp. 16–30. [Online]. Available: <http://dl.acm.org/citation.cfm?id=1792838.1792841>
- [34] K. Czarnecki, C. H. P. Kim, and K. T. Kalleberg, “Feature models are views on ontologies,” in *SPLC*, 2006, pp. 41–51.
- [35] E. N. Haslinger, R. E. Lopez-Herrejon, and A. Egyed, “Reverse engineering feature models from programs’ feature sets,” in *Proceedings of the 2011 18th Working Conference on Reverse Engineering*, ser. WCRE ’11. Washington, DC, USA: IEEE Computer Society, 2011, pp. 308–312. [Online]. Available: <http://dx.doi.org/10.1109/WCRE.2011.45>
- [36] D. Benavides, S. Segura, and A. Ruiz-Cortés, “Automated analysis of feature models 20 years later: A literature review,” *Inf. Syst.*, vol. 35, no. 6, pp. 615–636, Sep. 2010. [Online]. Available: <http://dx.doi.org/10.1016/j.is.2010.01.001>
- [37] E. N. Haslinger, “Reverse engineering feature models from program configurations,” Linz, Austria, p. 131, September 2012.
- [38] P. Ye, X. Peng, Y. Xue, and S. Jarzabek, “A case study of variation mechanism in an industrial product line,” in *Proceedings of the 11th International Conference on Software Reuse: Formal Foundations of Reuse and Domain Engineering*, ser. ICSR ’09. Berlin,

Heidelberg: Springer-Verlag, 2009, pp. 126–136. [Online]. Available: http://dx.doi.org/10.1007/978-3-642-04211-9_13

- [39] D. Beuche, “Transforming legacy systems into software product lines,” in *Proceedings of the 13th International Software Product Line Conference*, ser. SPLC ’09. Pittsburgh, PA, USA: Carnegie Mellon University, 2009, pp. 321–321. [Online]. Available: <http://dl.acm.org.gate6.inist.fr/citation.cfm?id=1753235.1753290>
- [40] J. Rubin and M. Chechik, “A framework for managing cloned product variants,” in *Proceedings of the 2013 International Conference on Software Engineering*, ser. ICSE ’13. Piscataway, NJ, USA: IEEE Press, 2013, pp. 1233–1236. [Online]. Available: <http://dl.acm.org/citation.cfm?id=2486788.2486971>
- [41] J. Rubin and M. Chechik, “Locating distinguishing features using diff sets,” in *Proceedings of the 27th IEEE/ACM International Conference on Automated Software Engineering*, ser. ASE 2012. New York, NY, USA: ACM, 2012, pp. 242–245. [Online]. Available: <http://doi.acm.org/10.1145/2351676.2351712>
- [42] Y. Dubinsky, J. Rubin, T. Berger, S. Duszynski, M. Becker, and K. Czarnecki, “An exploratory study of cloning in industrial software product lines,” in *CSMR*, 2013, pp. 25–34.
- [43] L. Linsbauer, E. R. Lopez-Herrejon, and A. Egyed, “Recovering traceability between features and code in product variants,” in *Proceedings of the 17th International Software Product Line Conference*, ser. SPLC ’13. New York, NY, USA: ACM, 2013, pp. 131–140. [Online]. Available: <http://doi.acm.org.gate6.inist.fr/10.1145/2491627.2491630>
- [44] B. Ganter and R. Wille, *Formal Concept Analysis: Mathematical Foun-*

dations, 1st ed. Secaucus, NJ, USA: Springer-Verlag New York, Inc., 1997.

- [45] M. Barbut and B. Monjardet, *Ordre et classification: algèbre et combinatoire*, ser. Collection Hachette université: Méthodes mathématiques des sciences de l’homme. Hachette, 1970. [Online]. Available: <http://books.google.fr/books?id=n3BpSgAACAAJ>
- [46] Z. Azmeh, “A web service selection framework for an assisted soa,” Ph.D. dissertation, LIRMM - University of Montpellier 2, Montpellier, France, October 2011.
- [47] P. Valtchev, R. Godin, R. Missaoui, M. Huchard, A. Napoli, D. Grosser, C. Roume, A. M. Rouane-Hacene, J. Zuo, C. Frambourg, L. Szathmary, K. Nehme, and A. Diop. (2005) Galicia lattice builder home page. [Online]. Available: <http://www.iro.umontreal.ca/~galicia/>
- [48] S. Yevtushenko, J. Tane, T. B. Kaiser, S. Objedkov, J. H. Correia, and H. Reppe. (2006) The concept explorer. [Online]. Available: <http://conexp.sourceforge.net/>
- [49] R. Godin and H. Mili, “Building and maintaining analysis-level class hierarchies using galois lattices,” *SIGPLAN Not.*, vol. 28, no. 10, pp. 394–410, Oct. 1993. [Online]. Available: <http://doi.acm.org/10.1145/167962.165931>
- [50] F. Loesch and E. Ploedereder, “Optimization of variability in software product lines,” in *Proceedings of the 11th International Software Product Line Conference*, ser. SPLC ’07. Washington, DC, USA: IEEE Computer Society, 2007, pp. 151–162. [Online]. Available: <http://dx.doi.org/10.1109/SPLINE.2007.31>

- [51] U. Ryssel, J. Ploennigs, and K. Kabitzsch, “Extraction of feature models from formal contexts,” in *Proceedings of the 15th International Software Product Line Conference, Volume 2*, ser. SPLC ’11. New York, NY, USA: ACM, 2011, pp. 4:1–4:8. [Online]. Available: <http://doi.acm.org/10.1145/2019136.2019141>
- [52] J.-R. Falleri and X. Dolques. (2010) erca - eclipse’s relational concept analysis - google project hosting. [Online]. Available: <https://code.google.com/p/erca>
- [53] G. Arévalo, A. Berry, M. Huchard, G. Perrot, and A. Sigayret, “Performances of galois sub-hierarchy-building algorithms,” in *Proceedings of the 5th international conference on Formal concept analysis*, ser. ICFCA’07. Berlin, Heidelberg: Springer-Verlag, 2007, pp. 166–180. [Online]. Available: <http://dl.acm.org/citation.cfm?id=1759618.1759629>
- [54] A. Berry, M. Huchard, A. Napoli, and A. Sigayret, “Hermes: an efficient algorithm for building galois sub-hierarchies,” in *CLA*, 2012, pp. 21–32.
- [55] R. Al-Msie’deen, A. Seriai, M. Huchard, C. Urtado, and S. Vauttier, “Mining features from the object-oriented source code of software variants by combining lexical and structural similarity,” in *Proceedings of the 13th International Conference on Information Reuse and Integration*, 2013.
- [56] M. Acher, A. Cleve, G. Perrouin, P. Heymans, C. Vanbeneden, P. Collet, and P. Lahire, “On extracting feature models from product descriptions,” in *Proceedings of the Sixth International Workshop on Variability Modeling of Software-Intensive Systems*, ser. VaMoS ’12. New York, NY, USA: ACM, 2012, pp. 45–54. [Online]. Available: <http://doi.acm.org/10.1145/2110147.2110153>
- [57] D. Grossman and O. Frieder, *Information Retrieval: Algorithms and*

- Heuristics*, ser. Kluwer international series in engineering and computer science. Springer, 2004. [Online]. Available: <http://books.google.fr/books?id=cpE714KbcLUC>
- [58] B. Dit, M. Revelle, M. Gethers, and D. Poshyvanyk, “Feature location in source code: a taxonomy and survey,” *Journal of Software: Evolution and Process*, vol. 25, no. 1, pp. 53–95, 2013.
- [59] X. Yinxing, “Reengineering legacy software products into software product line,” Ph.D. dissertation, National university of singapore, jan. 2013. [Online]. Available: <http://scholarbank.nus.edu.sg/handle/10635/36403>
- [60] S. C. Deerwester, S. T. Dumais, T. K. Landauer, G. W. Furnas, and R. A. Harshman, “Indexing by latent semantic analysis,” *JASIS*, vol. 41, no. 6, pp. 391–407, 1990.
- [61] J. Cullum and R. Willoughby, *Lanczos Algorithms for Large Symmetric Eigenvalue Computations: Volume 1, Theory*, ser. Classics in Applied Mathematics. Society for Industrial and Applied Mathematics, 2002. [Online]. Available: <http://books.google.fr/books?id=CYHTR2nt2twC>
- [62] W. Frakes and R. Baeza-Yates, *Information retrieval: data structures and algorithms*. Prentice Hall, 1992. [Online]. Available: <http://books.google.fr/books?id=IJgpAQAAMAAJ>
- [63] M. Berry and M. Browne, *Understanding Search Engines: Mathematical Modeling and Text Retrieval*, ser. ITPro collection. Society for Industrial and Applied Mathematics, 1999. [Online]. Available: <http://books.google.fr/books?id=PaNagzMsRd4C>
- [64] S. W. Thomas, “Mining software repositories with topic models,” School of Computing, Queen’s University, Tech. Rep. 2012-586, 2012.

- [65] S. T. Dumais, “Lsi meets trec: A status report,” in *TREC*, 1992, pp. 137–152.
- [66] D. Poshyvanyk, A. Marcus, V. Rajlich, Y.-G. Guéhéneuc, and G. Antoniol, “Combining probabilistic ranking and latent semantic indexing for feature identification,” in *ICPC*, 2006, pp. 137–148.
- [67] T. F. Bissyande, F. Thung, S. Wang, D. Lo, L. Jiang, and L. Reveillere, “Empirical evaluation of bug linking,” in *Proceedings of the 2013 17th European Conference on Software Maintenance and Reengineering*, ser. CSMR ’13. Washington, DC, USA: IEEE Computer Society, 2013, pp. 89–98. [Online]. Available: <http://dx.doi.org/10.1109/CSMR.2013.19>
- [68] S. T. Dumais, G. W. Furnas, T. K. Landauer, S. Deerwester, and R. Harshman, “Using latent semantic analysis to improve access to textual information,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI ’88. New York, NY, USA: ACM, 1988, pp. 281–285. [Online]. Available: <http://doi.acm.org/10.1145/57167.57214>
- [69] C. Fellbaum, *WordNet: An Electronic Lexical Database*, ser. Language, speech, and communication. MIT Press, 1998. [Online]. Available: <http://books.google.fr/books?id=Rehu8OOzMIMC>
- [70] E. Garcia, “Latent semantic indexing (LSI) a fast track tutorial,” October 21, 2006.
- [71] C. McMillan, D. Poshyvanyk, and M. Revelle, “Combining textual and structural analysis of software artifacts for traceability link recovery,” in *Proceedings of the 2009 ICSE Workshop on Traceability in Emerging Forms of Software Engineering*, ser. TEFSE ’09. Washington, DC, USA: IEEE Computer Society, 2009, pp. 41–48. [Online]. Available: <http://dx.doi.org/10.1109/TEFSE.2009.5069582>

- [72] A.-E. E. Hamdouni, A. Seriali, and M. Huchard, “Component-based architecture recovery from object oriented systems via relational concept analysis,” in *CLA*, 2010, pp. 259–270.
- [73] S. Budhkar and A. Gopal, “Component-based architecture recovery from object oriented systems using existing dependencies among classes,” *International Journal of Computational Intelligence Techniques*, vol. 3, no. 1, pp. 56–59, 2012. [Online]. Available: http://www.bioinfo.in/uploadfiles/13470800423_1_1_IJCIT.pdf
- [74] R. Al-Msie'deen, A. Seriali, M. Huchard, C. Urtado, S. Vauttier, and H. E. Salman, “Feature location in a collection of software product variants using formal concept analysis,” in *ICSR*, 2013, pp. 302–307.
- [75] A. Marcus and J. I. Maletic, “Recovering documentation-to-source-code traceability links using latent semantic indexing,” in *Proceedings of the 25th International Conference on Software Engineering*, ser. ICSE '03. Washington, DC, USA: IEEE Computer Society, 2003, pp. 125–135. [Online]. Available: <http://dl.acm.org/citation.cfm?id=776816.776832>
- [76] M. V. Couto, M. T. Valente, and E. Figueiredo, “Extracting software product lines: A case study using conditional compilation,” in *Proceedings of the 2011 15th European Conference on Software Maintenance and Reengineering*, ser. CSMR '11. Washington, DC, USA: IEEE Computer Society, 2011, pp. 191–200. [Online]. Available: <http://dx.doi.org/10.1109/CSMR.2011.25>
- [77] J.-M. Davril, E. Delfosse, N. Hariri, M. Acher, J. Cleland-Huang, and P. Heymans, “Feature model extraction from large collections of informal product descriptions,” in *Proceedings of the 2013 9th Joint Meeting on Foundations of Software Engineering*, ser. ESEC/FSE 2013.

New York, NY, USA: ACM, 2013, pp. 290–300. [Online]. Available: <http://doi.acm.org/http://dx.doi.org/10.1145/2491411.2491455>

- [78] R. Al-Msie'deen, A. Seriai, M. Huchard, C. Urtado, S. Vauttier, and H. E. Salman, "Mining features from the object-oriented source code of a collection of software variants using formal concept analysis and latent semantic indexing," in *Proceedings of The 25th International Conference on Software Engineering and Knowledge Engineering*, 2013, pp. 244–249. [Online]. Available: <http://index.ksi.edu/conf/seke/2013/cr/171.pdf>
- [79] M. Grechanik, K. S. McKinley, and D. E. Perry, "Recovering and using use-case-diagram-to-source-code traceability links," in *PESEC-FSE '07*. ACM, 2007, pp. 95–104.
- [80] Y. Yang, X. Peng, and W. Zhao, "Domain feature model recovery from multiple applications using data access semantics and formal concept analysis," in *Proceedings of the 2009 16th Working Conference on Reverse Engineering*, ser. WCRE '09. Washington, DC, USA: IEEE Computer Society, 2009, pp. 215–224. [Online]. Available: <http://dx.doi.org/10.1109/WCRE.2009.15>
- [81] S. Duszynski, J. Knodel, and M. Becker, "Analyzing the source code of multiple software variants for reuse potential," in *Proceedings of the 2011 18th Working Conference on Reverse Engineering*, ser. WCRE '11. Washington, DC, USA: IEEE Computer Society, 2011, pp. 303–307. [Online]. Available: <http://dx.doi.org/10.1109/WCRE.2011.44>
- [82] H. Eyal-Salman, A.-D. Seriai, and C. Dony, "Feature-to-code traceability in a collection of software variants: Combining formal concept analysis and information retrieval," in *Proceedings of the 13th International Conference on Information Reuse and Integration*, 2013, pp. 209–216.

- [83] M. Acher, A. Cleve, P. Collet, P. Merle, L. Duchien, and P. Lahire, “Reverse engineering architectural feature models,” in *Proceedings of the 5th European conference on Software architecture*, ser. ECSA’11. Berlin, Heidelberg: Springer-Verlag, 2011, pp. 220–235. [Online]. Available: <http://dl.acm.org/citation.cfm?id=2041790.2041822>
- [84] G. Becan, “Reverse engineering feature models in the real,” UR1 - University of Rennes 1, Internship report 39, June 2013. [Online]. Available: <http://dumas.ccsd.cnrs.fr/dumas-00855005>
- [85] K. Czarnecki and A. Wasowski, “Feature diagrams and logics: There and back again,” in *Proceedings of the 11th International Software Product Line Conference*, ser. SPLC ’07. Washington, DC, USA: IEEE Computer Society, 2007, pp. 23–34. [Online]. Available: <http://dx.doi.org/10.1109/SPLC.2007.19>
- [86] N. Weston, R. Chitchyan, and A. Rashid, “A framework for constructing semantically composable feature models from natural language requirements,” in *Proceedings of the 13th International Software Product Line Conference*, ser. SPLC ’09. Pittsburgh, PA, USA: Carnegie Mellon University, 2009, pp. 211–220. [Online]. Available: <http://dl.acm.org/citation.cfm?id=1753235.1753265>
- [87] H. Dumitru, M. Gibiec, N. Hariri, J. Cleland-Huang, B. Mobasher, C. Castro-Herrera, and M. Mirakhorli, “On-demand feature recommendations derived from mining public product descriptions,” in *Proceedings of the 33rd International Conference on Software Engineering*, ser. ICSE ’11. New York, NY, USA: ACM, 2011, pp. 181–190. [Online]. Available: <http://doi.acm.org/10.1145/1985793.1985819>
- [88] K. Czarnecki, S. She, and A. Wasowski, “Sample spaces and feature models: There and back again,” in *Proceedings of the 2008*

- 12th International Software Product Line Conference*, ser. SPLC '08. Washington, DC, USA: IEEE Computer Society, 2008, pp. 22–31. [Online]. Available: <http://dx.doi.org/10.1109/SPLC.2008.49>
- [89] V. Alves, C. Schwanninger, L. Barbosa, A. Rashid, P. Sawyer, P. Rayson, C. Pohl, and A. Rummler, “An exploratory study of information retrieval techniques in domain analysis,” in *Proceedings of the 2008 12th International Software Product Line Conference*, ser. SPLC '08. Washington, DC, USA: IEEE Computer Society, 2008, pp. 67–76. [Online]. Available: <http://dx.doi.org/10.1109/SPLC.2008.18>
- [90] R. E. Lopez-Herrejon, J. A. Galindo, D. Benavides, S. Segura, and A. Egyed, “Reverse engineering feature models with evolutionary algorithms: An exploratory study,” in *Proceedings of the 4th International Conference on Search Based Software Engineering*, ser. SSBSE'12. Berlin, Heidelberg: Springer-Verlag, 2012, pp. 168–182. [Online]. Available: http://dx.doi.org/10.1007/978-3-642-33119-0_13