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A Systematic Mapping of Configuration Management Activities in Software Product Line

Gonzalo P. Espinel-Mena
(Universidad de las Fuerzas Armadas - ESPE, Sangolquí, Ecuador
https://orcid.org/0000-0001-6213-7836, gpespinel@espe.edu.ec)

José L. Carrillo-Medina
(Universidad de las Fuerzas Armadas - ESPE, Sangolquí, Ecuador
https://orcid.org/0000-0001-5222-4039, jlcarrillo@espe.edu.ec)

Eddie E. Galarza
(Universidad de las Fuerzas Armadas - ESPE, Sangolquí, Ecuador
https://orcid.org/0000-0001-6121-7092, eegalarza@espe.edu.ec)

Mario Matias Urbieta
(Universidad Nacional de La Plata, La Plata, Argentina
https://orcid.org/0000-0002-4508-1209, murbieta@lifia.info.unlp.edu.ar)

Abstract: In the software product line (SPL), configuration management (CM) is a multidimensional problem that is taking great attention in software development. Although much research has been developed on this topic, there is no clear view of the current state of it. In this study, we used a systematic method to develop a map of configuration management across product lines to classify relevant literature. The resulting map provides an overview of this research through the identification of the main activities of the CM, the types and trends of research as well as the maturity of existing contributions. Because the CM in SPL is still in its formative stage, we believe that this work will contribute to the process of providing a more common and coherent conceptual basis for its understanding. In addition, it can help to detect important research problems and gaps.

Keywords: software product line, system family, configuration management, mapping study
Categories: D.2.9
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1 Introduction

SPL refers to a set of software-intensive products that: (i) share a set of common and managed features; (ii) meet the specific needs of a certain market segment (domain); and (iii) are developed from a common set of core assets by default [Pohl et al., 2005]. The benefits of adopting SPL depend on the context in which it is applied. Some of the most common benefits are the reduced costs and times to market promoted by reusing a core asset base. To achieve systematic reuse, product line engineering is based on two basic concepts, domain engineering and application engineering [Weiss and Lai, 1999]. In domain engineering, a product line platform is created, which then becomes the basis from which a specific product can be developed. In application engineering, the derivation of products from the product line takes place. A central concept for domain

and application engineering is CM. The CM is, of course, an integral part of any software development activity and takes on special significance in the context of the product line.

Moreover, the emergence of distributed technologies, the unprecedented growth of component-based and service-oriented systems, pose increasing challenges to CM in SPL. Very few approaches are found on CM in SPL, although CM is mature enough for traditional products which are tailor-made, and they are inadequate to provide a general solution. In other words, a comprehensive approach to CM in SPL is still necessary.

Despite some good preliminary results in this field [Farahani and Habibi, 2016b, Soujanya and Rao, 2015, Bendix et al., n.d., Laqua and Knauber, n.d., Yu and Ramaswamy, 2006], this study includes the complexity of managing the variability and dependencies between components, and at the same time maintaining consistency and integrity. The control of versions and traceability are crucial and extensive testing can be costly. In addition, the configuration management (CM) solution based in the software product line (SPL) overlaps with several research fields and, consequently, creates difficulties in understanding the area which has raised a number of questions among researchers interested in this topic. Some researchers have had difficulty understanding the context over others research topics and at the same time, the way it can contribute to their fields of research. In any domain, where there are multiple interrelated software products that share a common code base or an underlying architecture, can give benefits from configuration management activities across an entire software product line, this helps to ensure that all products are well coordinated, maintain consistency and enable effective release and change management [Capilla et al., 2012].

Therefore, trying to minimise the problem, this paper proposes to systematically investigate the preliminary studies related to CM in SPL and characterise this topic, mapping the studies found in a common classification scheme.

As a result, it is expected to provide an overview of the research area, identifying the types and amount of research, as well as the contributions already available within the field. In addition, this study should provide the basis for detecting important research aspects, gaps, and trends in the area of CM in SPL.

This article is organised as follows. Section 2 describes the methodological process of the research. Section 3 presents the classification scheme, section 4 describes the results obtained from the mapping study process, section 5 discusses important points related with this field and finally, section 6 presents final conclusions and guidelines for future work.

2 Research Methodology

Some papers have been published related to the application of Systematic Mapping Studies (SMS) in different areas of software engineering [Budgen et al., n.d., Petersen et al., 2008, Espinel et al., 2022]. SMS are designed to give an overview of a research area through the classification and counting of contributions in relation to the categories of that classification [Petersen et al., 2008, Kitchenham and Charters, 2007]. It is a search in literature to know what topics have been covered in it and where it has been published [Petersen et al., 2008].

The purpose of this study is to investigate in more detail the CM approach in the SPL to build a classification scheme and structure in the field of Configuration Management within the Software Product Line. As a result, it is expected to provide an overview of the research area identifying the types and amount of research, as well as the type of contributions available in this field. In addition, this mapping study should provide the basis for detecting important research aspects, trends, and challenges in the field of CM in SPL.

As a first activity in this study, we develop a protocol, i.e., a plan to define the basic procedures of the mapping study, which has been specified based on the process and guidelines defined in [Budgen et al., n.d.] and [Petersen et al., 2008]. This protocol is subdivided into phases: 1) Definition of research questions, 2) Conduct search, 3) Screening of papers, 4) Keywording using abstracts, and 5) Data extraction and mapping process. Each of these phases is an SMS step and are shown below.

Definition of Research Questions

An essential step of any mapping study is the definition of your research question. This question will be responsible for guiding all subsequent steps of the process, including: (i) conducting the search for relevant papers, (ii) screening of papers, (iii) keywords of abstracts, and (iv) data extraction and mapping. Therefore, to address the points described above, this mapping study will focus on answering the following question:

RQ: How is the field of CM structured in the SPL and what is the maturity of existing contributions?

The research questions were defined based on the authors' experience in this area, and at the same time, based on discussions with experts in the field of related knowledge. As the research question is considering many aspects, it was divided into sub questions grouped into two categories: 1) Overview and 2) Maturity of contributions, as follows:

Overview.

RQ1: What CM activities in the SPL have been addressed and how many articles cover the different activities?

The objective of this question is to identify the main areas of research within the field of CM in SPL and the representativeness of these areas to structure the field and form the basis for building a classification scheme of the main existing approaches.

Maturity of contributions.

RQ2: What types of contributions have been made and what types of research have been carried out in the different activities of the CM in SPL?

This question aims to determine the degree of maturity of these contributions by analysing the types of research that have been conducted in the existing studies so far.

Conduct Search for Primary Studies

The search string used to identify the literature for the mapping study is defined according to the population of articles to which it is intended and the intervention to which it refers. The population comprises software domain, product lines, product families, and system families. The intervention refers to configuration management, which involves practices, techniques, methods, and processes. The resulting search string is: (software) AND ("product line" OR "product-line" OR "product family" OR "program family" OR "system family" OR "SPL") AND ("configuration management") AND (method OR process OR model OR tool OR metric OR "techni*" OR algorithm OR framework OR "strateg*").

The search process for this mapping began with an automated search, followed by the review of the references of the selected studies in a process usually called a "snowball" [Wohlin et al., 2012]. For automated search we used search engines of the most important digital libraries (DLs) in the area of Software Engineering. [Kitchenham et al., 2009], such as Scopus DL (www.scopus.com), as well as IEEE Xplore (ieeexplore.ieee.org) and ACM DL (dl.acm.org). The automated search was based solely on the Metadata of the articles, and it was restricted to the field of "Software Engineering" when the search engine allowed the required filtering. For all sources we used the resulting search string.

Once the search strings were evaluated, they were used in the search engine of the selected DLs to obtain the candidate studies. Then, the selection process followed these stages:

Stage 1: Run the search string on the DLs.
Stage 2: Eliminate duplicate studies.
Stage 3: Select studies by title and abstract.
Stage 4: Select the studies by the full text.

The research team reviewed the references of each resulting primary study after Stage 4 to identify any additional primary candidate studies that were not already included in the selected primary studies. Those items then had to go through the same selection stages.

Figure 1 shows the study selection process and the number of studies selected at each stage. The red boxes show the total number of items obtained from each DL. The boxes on the left contain the number of resulting papers after each stage of the automatic search. The boxes on the right contain the number of papers resulting after each selection stage for the reference search (snowball), which was performed using 32 papers obtained through the automated search.

The main author of the study conducted the search and determined the best way to maintain a fair judgement on the selected studies. The other authors reviewed the included studies, checking the inclusion and exclusion criteria. The search was limited to a defined time period.

The authors conducted an experimental study with selected samples to assess inclusion and exclusion criteria with a random sample of 10 articles, and a large consensus was reached. After the pilot testing, two of the authors selected the remaining articles by reading the abstracts and marked them as included, excluded, or uncertain. At the end, the authors reviewed all disagreements by analysing the selected studies

and conflicts were resolved through discussion. After the selection process, a total of 34 relevant papers remained.

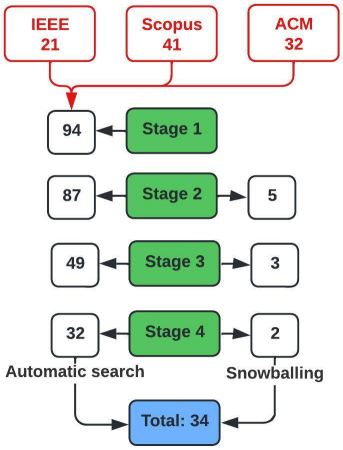

Figure 1: Study selection process

Screening of Papers for Inclusion and Exclusion

To remain on the list of candidates of selected papers, they needed to be written in English, published until March 2023, and address at least one of the activities of the configuration management of a software product (change management, version management, construction management and/or release management) [Sommerville, n.d.].

Grey literature studies were not included in this analysis, based on the assumption that good studies of this nature usually appear as journal or conference papers [Kitchenham et al., 2010]. The exclusion criteria were:

- Studies that do not address at least one of the activities of the configuration management of a software product;
- Studies in the form of essay, abstract, presentation, poster, short paper (less than 5 pages);
- Papers summarising the results of existing research studies (e.g., reviews, planning, surveys, etc.);
- Duplicate papers;
- Finally, papers that cannot be accessed from DLs and that could not be obtained by contacting the authors.

Keywording of Abstracts

CM is, of course, an integral part of any software development activity and acquires special importance in the context of the product line [‘A Framework for Software Product Line Practice, Version 5.0’, n.d.]. In the past, some classifications of CM

oriented to the development of a single product have been made. As these classifications are not based on a large sample of the literature on product lines, there is a risk that various important categories may be missing. Therefore, we decided to follow a keyword strategy to develop a classification scheme. The keyword process helps reviewers to define a set of categories representative of the underlying population and ensures that the schema takes into account relevant studies. [Petersen et al., 2008] clearly describes the systematic keyword process adopted for the creation of the scheme. Section 3 presents the resulting classification scheme.

Data Extraction and Mapping of Studies

In this phase we mapped each included article to a particular intersection established in the scheme. We guided the process by the definitions of the categories identified during the development of the classification scheme described in Section 3. The map produced a clear picture of the dispersed past research across multiple facets. This allowed us to analyse the results properly and at the same time to focus on the frequency of publications, thus, determining the coverage of the field of research. Different facets of the scheme we combined to answer specific research questions.

3 Classification Scheme

We used the idea of categorising studies in terms of facets, as described by Petersen et al. [Petersen et al., 2008]. Thus, based on the classification scheme defined in the presented examples, the classification scheme was structured in three facets: (i) research approach, (ii) type of contribution, and (iii) type of research.

The first two facets were developed during the keyword process and the third was based on the classification of research articles described by Wieringa et al. [Wieringa et al., 2006]. This facet Type of research, according to Petersen et al. [Petersen et al., 2008], can be reused as a basis for classifying studies in any research field. It was therefore felt that this facet could help to identify the maturity of existing contributions. The specification of the facets with a description for each category adopted, is presented in Tables 1, 2 and 3.

Category	Description
Change Management	It supports decision-making and keeps records of all changes made to a product during maintenance and development processes.
Version Management	Controls versions of existing assets to support production of a valid desired system configuration.
Build Management	Refers to creating the final product by compiling and linking the correct versions of the components.
Release Management	It deals with delivering and defining the correct components of a system that constitute the product.

Table 1: Research focus (Facet 1)

Category	Description
Process	Describes the activities or actions and their workflow.
Method	It describes the rules of how things should be done, for example, the rules for building a model for managing a change. In this category, algorithms are also considered.
Model	It is a description of the real world that omits details. To be considered in this category, the model must have a high degree of formality, i.e., it must have semantics and notations (for example, feature models).
Tool	A software tool is developed to support different aspects of software configuration management.
Technique	A defined systematic procedure that helps evaluating and improving the configuration management process.

Table 2: Contribution type (Facet 2)

Category	Description
Validation Research	The techniques investigated are novel and have not yet been implemented in practice. The techniques used are, for example, experiments, i.e., work done in the laboratory.
Evaluation Research	The techniques are implemented in practice and an evaluation of the technique is carried out, i.e., it is shown how the technique is implemented in practice (implementation of the solution) and what are the consequences of the implementation in terms of benefits and disadvantages (evaluation of the implementation).
Solution Proposal	A solution is proposed for a problem, the solution can be novel or a significant extension of an existing technique. The potential benefits and applicability of the solution are shown by an example or a good line of argument.
Philosophical Papers	These articles describe a new way of looking at existing things, structuring the field in the form of a taxonomy or conceptual framework.
Opinion Papers	These articles express an opinion about if a certain technique is good or bad, or how things should be done. They are not based on related work or research methodologies.
Experience Papers	What and how something has been done in practice. It must be the author's personal experience.

Table 3: Research type (Facet 3)

4 Mapping

With the classification scheme established, the mapping process began, categorising the relevant studies in each facet and then making a combination between the results found in the three facets. In this section, the results of the mapping in the research focus facet are described, and in the next one, a discussion is presented about the combination of the three facets.

The results of the categorization of the studies are presented in Table 4, which contains the relevant information of selected studies (general characteristics of the studies, summary of the contribution and category(s) of each facet) required to generate the distribution map of the selected studies on the research focus (Figure 2) and for calculating the frequencies of the studies in each category of the classification scheme (Figure 3). This allows us to analyse how the activities of the CM are addressed in the SPL, the type of research and contributions that have been made in the different activities of CM in SPL, and thus, answering the proposed research questions.

1. RQ1: What CM activities in the SPL have been addressed and how many articles cover the different activities?
   Through the keyword search process, the categories of the research focus facet were identified, which correspond to the activities of the CM: change management, version management, build management and release management. Figure 2 shows the distribution of the selected studies on the research focus, where 34 articles cover at least one of the categories of the research focus. 11.76% of studies focus on change management (4 articles); 35.29% focus on version management (12 articles); 70.59% refer to build management (24 articles); and the rest address release management, i.e., 2.94% (1 article).

2. RQ2: What types of contributions have been made and what types of research have been carried out in the different activities of the CM in SPL?
   To answer this question, a bubble diagram was made, representing the interconnected frequencies, where the relationship between the activities of the CM vs the types of contribution (Figure 3: left side of the X-axis) and the activities of the CM vs. types of research can be clearly and accurately visualised (Figure 3: right side of the X-axis). The number of articles on each side of the X-axis may differ, as some articles provide multiple contributions.As an example, an article on the build management activity could present a method and a tool as a result of the proposed activity [Burégio et al., 2010].

   Regarding the distribution of the types of contribution, in the categories of the research focus (Figure 3: left side of the X-axis) there is 30.56% of contributions (totaling 11 methods described in 11 articles of the 14 methods that address at least one activity of the CM) that guide the creation of a type method. Taking into account the methods and tools, it turns out to have a percentage of 58.34% of the total contributions (totaling 21 methods and/or tools described in 20 articles of the 24 methods and/or tools that address at least one activity of the CM), 22. 22% of contributions report models (totaling 8 models described in 8 articles of the 12 models addressing at least one

activity of the CM), 16.67% of contributions describe processes (6 processes described in 6 articles address at least one activity of the CM), and 2.78% of contributions present a technique (1 technique described in 1 article addresses at least one activity of the CM)

From the analysis of the map (Figure 3: right side of the X-axis), it is observed that the most frequent type of research is the solution proposals with a 70.59% of research described in 24 articles, 17.65% of research presents validation research described in 6 articles, and 11.76% of research described in 4 articles are articles based on experience. No article reports evaluation of proposals, philosophical documentation, or opinion.

ID	**Attributes**	**Information extracted**				
01 [Ananieva et al., 2022]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	VM	Facet 2:	Model	Facet 3:	Solution Proposal
02 [Amraoui et al., 2022]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Process	Facet 3:	Solution Proposal

03 [Owdeh and Sayyad, 2021]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Method	Facet 3:	Solution Proposal
04 [Tuglular and Coskun, 2021]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Method	Facet 3:	Solution Proposal
05 [Pinnecke, 2021]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Method	Facet 3:	Solution Proposal

06 [Etedali et al., 2021]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Tool	Facet 3:	Validation Research
07 [Uz Zaman et al., 2021]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Tool	Facet 3:	Validation Research
08 [Grüner et al., 2020]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Process	Facet 3:	Experience Paper

09 [Rodas-Silva et al., 2019]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Tool	Facet 3:	Solution Proposal
10 [Farahani and Habibi, 2019]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Method	Facet 3:	Solution Proposal
11 [Krieter et al., 2019]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Method	Facet 3:	Validation Research

12 [Soujanya, 2018]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	ChM, VM	Facet 2:	Method	Facet 3:	Validation Research
13 [Krueger and Clements, 2019]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Tool, Method	Facet 3:	Solution Proposal
14 [Kuiter et al., 2018]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Process	Facet 3:	Experience Paper

15 [Etedali et al., 2017]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Tool	Facet 3:	Solution Proposal
16 [Hayashi et al., 2017]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Method	Facet 3:	Solution Proposal
17 [Linsbauer et al., 2016]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	VM	Facet 2:	Process, Tool	Facet 3:	Solution Proposal

18 [Hellebrand et al., 2016]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	VM	Facet 2:	Model	Facet 3:	Solution Proposal
19 [Farahani and Habibi, 2016a]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	ChM, VM, BM, RM	Facet 2:	Model	Facet 3:	Solution Proposal
20 [Farahani and Habibi, 2016b]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	ChM, VM	Facet 2:	Model	Facet 3:	Solution Proposal

21 [Schwägerl and Westfechtel, 2016a]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	VM	Facet 2:	Model	Facet 3:	Solution Proposal
22 [Camacho et al., 2016]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Model	Facet 3:	Solution Proposal
23 [Sion et al., 2016]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Tool	Facet 3:	Solution Proposal

24 [Schwägerl and Westfechtel, 2016b]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	VM	Facet 2:	Tool	Facet 3:	Solution Proposal
25 [Soujanya and AnandaRao, 2016]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	VM, BM	Facet 2:	Method	Facet 3:	Validation Research
26 [Fischer et al., 2015]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Model	Facet 3:	Experience Paper

27 [McVoy, 2015]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	VM	Facet 2:	Tool	Facet 3:	Solution Proposal
28 [Tsuchiya et al., 2015]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	ChM	Facet 2:	Method	Facet 3:	Validation Research
29 [Schwägerl et al., 2015]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	VM, BM	Facet 2:	Method	Facet 3:	Solution Proposal

30 [Acher et al., 2014]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	VM	Facet 2:	Process	Facet 3:	Experience Paper
31 [Sampath, 2014]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Method	Facet 3:	Solution Proposal
32 [Dayba and Oğuztüzün, 2012]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Model	Facet 3:	Solution Proposal

33 [Schroeter et al., 2012]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Process	Facet 3:	Solution Proposal
34 [Capilla et al., 2012]	Title:	A conceptual model for unifying variability in space and time: Rationale, validation, and illustrative applications				
	Authors:	Ananieva, S., Greiner, S., Kehrer, T., (...), Ramesh, S., Reussner, R.				
	Publication:	2022 Empirical Software Engineering, An International Journal				
	Contribution:	It describes how to build a conceptual model for unifying concepts of variability in space and time as well as their relations.				
	Facet 1:	BM	Facet 2:	Model	Facet 3:	Solution Proposal

ChM = Change Management, VM = Version Management, BM = Build Management, RM =Release Management; Facet 1 = Research Focus, Facet 2 = Contribution Type, Facet 3 = Research Type

Table 4: Information from data extraction of selected studies

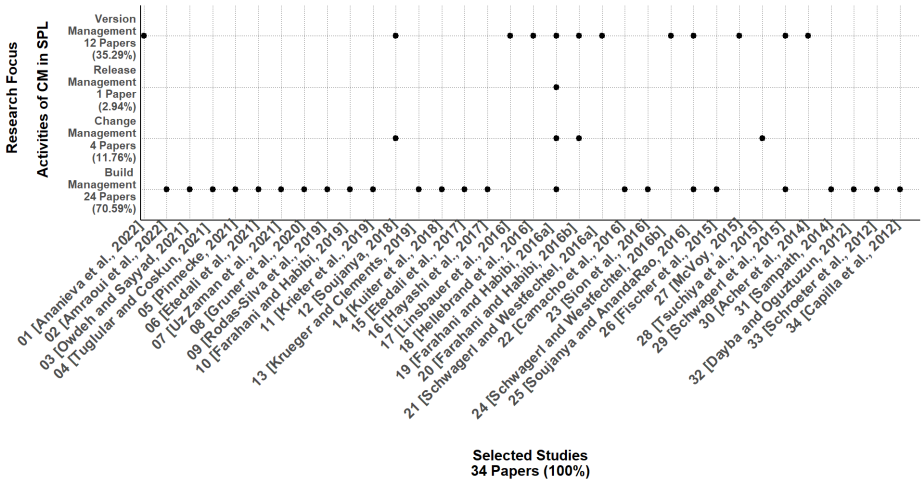

Figure 2: Studies distribution by research focus

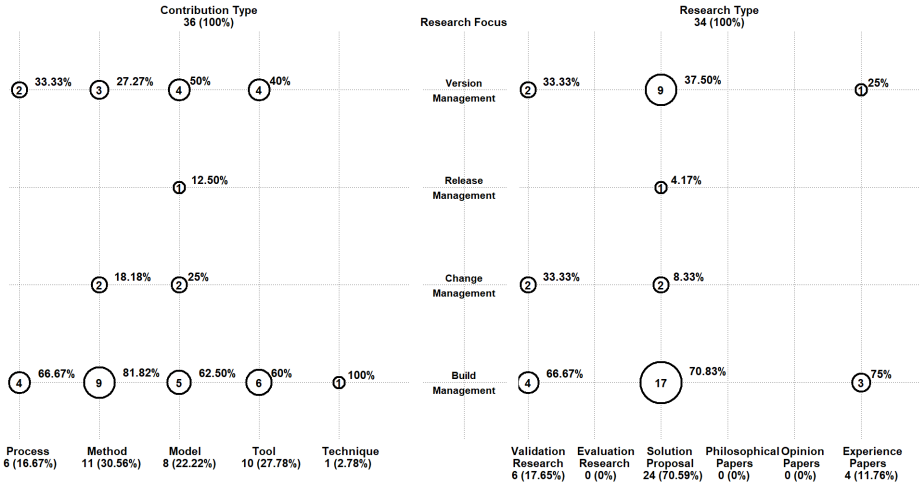

Figure 3: Activities maps of CM in the SPL. Y-axis shows the research focus; contribution type is on left side of the X-axis; and the research type is on the X-axis right side

5 Discussion

The results analysis presents the number of articles that coincide with each category addressed in this study. This makes it possible to determine which categories have been emphasised in past research and thus identify gaps and possibilities for future research

[Petersen et al., 2008]. The resulting map produces a clear picture of how past research is dispersed across multiple facets, helping us to intentionally analyse the results while focusing on publication frequencies, thus determining the coverage of the field of study. Different facets of the scheme are combined to answer specific research questions.

Insights

From the results obtained, the publication of articles on CM in SPL is increasing, in line with what is happening in other fields of Software Engineering. An indicator of this trend with respect to the year of publication of the selected studies is that approximately 73.53% (25 articles) are concentrated in recent years, from 2016 to 2022.

Another interesting fact found in this study is that of 94 candidate articles to be included in the mapping, 36.17% (34 articles) met the criteria to be finally accepted for data extraction. Therefore, considering the specificity of the research, it appeared that the search terms related to SPL and CM were adequate and stable enough to be used in the search string.

Contributions Considerations

From the analysis of the bubble diagram presented in Figure 3, it can be concluded that the largest set of contributions covering at least one of the activities of the CM in SPL is related to the solution proposals (approximately 71%). Most of them consider the development of methods and tools, and the others focus on models. This fact reinforces that the field of CM in SPL is still in its formation stage, because, added to the solution proposals and articles based on experience are in total 82.35% (28 articles), this indicates that there are few studies that deal with validation research, where the proposed contributions are novel and have not yet been implemented in practice, that is, only experimental work has been carried out.

On the other hand, there is no evaluation research, which shows how the contribution is implemented in practice and what are the consequences of implementation in terms of benefits and disadvantages in the industry. Therefore, it is difficult to find articles of experience or opinion that present the applicability of CM ideas in SPL in an industrial context. It should be noted that few processes and techniques have been proposed, and that most of the existing contributions are in a validation stage and are not yet being used in a real industrial context, due to the absence of an evaluation stage. Finally, it can be indicated that the presence of some experience articles (about 11.76%) shows that part of the Software Engineering community cares about contributing and sharing knowledge to reach a common base in the study.

Consideration related to validity

Some considerations related to the validity of the present study can be highlighted: (i) *Recent research area*: since CM in SPL is a relatively new area of knowledge, the results obtained should be carefully analysed due to the still small number of studies; (ii) *Several related fields*: CM in SPL overlaps with several research fields, which could create difficulties in understanding some specific or unknown topics; (iii) *Research questions*: the set of defined questions may not cover the whole scope of CM in SPL. This implies that the reader might not find answers to the questions of interest. As this was a feasible consideration related to validity, several discussion meetings were held

with members of the research team to fine-tune the questions. (iv) *Search performed:* the search engines of the DLs do not have compatible search rules. It is not possible to know all the rules used by each engine to search for a document. This threat was mitigated by adapting the search string to each digital database.

6 Conclusions

In this article, Configuration Management activities in the Software Product Line are categorised through a mapping study on a set of existing jobs. The research methodology adopted is described, a classification scheme is presented to categorise the studies, the results obtained are shown and a discussion about the results is made.

The systematic map shows that most of the research has focused on developing methods, tools, and models for dealing with build management and version management. There are relatively few contributions on the implementation of change management and release management. The main type of research has been of solution proposals type, followed by validation research and experience papers. According to the study, there appears to be a relative lack of research on tools, processes and techniques for change management and release management in the software product line.

Since the field is still in its initial phase, it is considered that this work can contribute as a conceptual basis to the understanding of CM activities in SPL. In addition, it can facilitate the detection of the main CM activities addressed, the types of research, gaps, and trends in the field of SPL. Future work will include applying this mapping study to a broader set of articles and adding questions to classify different aspects of the research area.

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