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Collaborative configuration approaches in software product lines engineering: A systematic mapping study

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ABSTRACT

In the context of software product line engineering, collaborative configuration is a decision-making process where multiple stakeholders contribute in building a single product specification. Several approaches addressing collaboration during configuration have already been proposed, but we still have little hard evidence about their effectiveness and little understanding about how collaborative configuration process should be carried out. This paper presents a classification framework to help understand existing collaborative configuration approaches. To elaborate it, a systematic mapping study was conducted guided by three research questions and 41 primary studies was selected out of 238 identified ones. The proposed framework is composed of four dimensions capturing main aspects related to configuration approaches: purpose, collaboration, process and tool. Each dimension is itself multi-faceted and a set of attributes is associated to each facet. Using this framework, we position and classify existing approaches, structure the representation of each approach characteristics, highlight their strengths and weaknesses, compare them to each other, and identify open issues. This study gives a solid foundation for classifying existing and future approaches for product lines collaborative configuration. Researchers and practitioners can use our framework for identifying existing research/technical gaps to attack, better scoping their own contributions, or understanding existing ones.

1. Introduction

Product configuration is a key activity in Software Product Line Engineering (SPLE) that refers to choosing a set of characteristics from a product line model (Clements and Northrop, 2001). Selected characteristics must comply with product line model constraints and user requirements (Salinesi et al., 2010). When the product line model is large, the number of possible configurations can be large too. Configuring this kind of models can be a hard, error-prone and time-consuming activity (Stein et al., 2014), which makes it a challenging activity for practitioners. Furthermore, it is hard to think of a single user solely responsible of a large number of configuration decisions (Mendonca et al., 2008). Rather, teamwork is highly desirable in order to cope with the general complexity of the configuration process.

Feature models (FMs) are widely used to represent product lines (Kang et al., 1990). They commonly span over several technical and non-technical knowledge domains, which requires the participation of multiple stakeholders with different knowledge and background (e.g. customer, product manager, software engineer, database administrator). Sharing the different configuration decisions by stakeholders is referred to as collaborative configuration process. It consists in three main activities (1) configuration role assignment, (2) the configuration itself and (3) conflicting situations management during the configuration (Mendonca et al., 2008).

Collaborative configuration of product lines has appealed to several researchers that addressed this topic differently where each approach focuses on a specific collaborative configuration aspect. In fact, some approaches such as Czarnecki et al. (2005), Mendonca et al. (2007),

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Mendonca et al. (2008), Rabiser et al. (2009) and Hubaux. et al. (2010) are interested in ensuring coordination of configuration activities through providing a pre-designed process. For some others such as Junior et al. (2011), Stein et al. (2014) and Ochoa and GonzÃ!'lez-Rojas (2016) the goal is to allow a free-order configuration process where stakeholders can freely express their requirements. Other ones focus on proposing state-sharing mechanism to increase stakeholders awareness and ensure global state consistency of distributed configuration. Finally, few approaches make a step forward to help stakeholders find a product that better meets their preferences by using recommendation techniques e.g. Stein et al. (2014) and Pereira (2017).

This variety of approaches may indicate that collaborative configuration can be carried out in different ways. Although quick overviews of collaborative configuration approaches are given in earlier papers, no extensive study has been reported so far for comparing collaborative configuration approaches within SPLE in a systematic way. We have little understanding of the different approaches, their salient characteristics and the differences between them.

The goal of this paper is to elaborate a classification framework to help understand existing approaches related to product line collaborative configuration through the identification of their current characteristics, shortcomings and challenges. To reach this overall goal, we defined three research questions:

- RQ1: What are the main characteristics of state-of-the-art approaches on the field of collaborative product line configuration?
  Rationale: By answering this RQ, we extract, classify and structure the characteristics of existing product line collaborative configuration approaches. This helps researchers in better understanding the state-of-the-art and have a comprehensive overview of the research area.
- RQ2: What are the strengths and weaknesses revealed from the comparative analysis of the existing collaborative configuration approaches?
  Rationale: by answering this RQ, we provide researchers with a strong and effective means to position an existing approach or their own one with respect to other existing ones, and to identify strengths and weaknesses of one approach against other ones. Furthermore, the full analysis of existing state-of-the-art approaches allows researchers and practitioners to understand the difference between these approaches and to choose the one that meets their needs.
- RQ3: What are the major challenges of collaborative configuration in the field of SPLE?
  Rationale: by answering this RQ, we identify the open issues related to the area which helps researchers focus their future efforts in the challenging directions.

To deal with these research questions, a framework called PL2C capturing the main characteristics of product line collaborative configuration approaches is elaborated. Some reports on comparative frameworks are published; e.g. to classify software product lines construction approaches (Ouali et al., 2011), to identify issues in scenario based approaches in requirements engineering (Rolland et al., 1998), and to give a classification and a comprehensive overview of collaboration approaches in e-learning (Al-Abri et al., 2017). The structure of the framework is inspired from these proposals. As for its enclosed information, it is obtained by carrying out a Systematic Mapping Study (SMS) according to the guidelines recommended by Petersen et al. (2015).

The rest of this paper is organized as follows: Section 2 gives a background of product line collaborative configuration process. Section 3 presents the process followed in the systematic mapping study for PL2C framework elaboration. Section 4 is devoted to the mapping study results, while Section 5 presents the framework proposed in this paper. Section 6 reports the framework-based analysis of the identified primary studies. Section 7 presents a description of the identified challenges. Section 8 analyzes some comparative frameworks found in literature and Section 9 discusses the threats to validity. Finally, Section 10 concludes the paper.

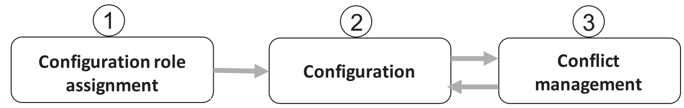

Fig. 1. Collaborative configuration process overview.

2. Background

Configuration of product line models can be achieved in many different ways. Configuration can be progressive where the variability of the product line model is eliminated on several specialization steps (Czarnecki et al., 2005), or staged where the configuration is conducted in several stages in order to adhere to a change of constraints in each of these stages, such as the development cost per year (Rabiser et al., 2009; Hubaux. et al., 2010). Configuration can also be carried in one shot where elements of the product line model, i.e. features, that meet the user's requirements are simply selected in a single step from the product line model (Djebbi, 2011). The selection of features is quite straightforward when it relies on an individual interaction with product line model presented as tree-like structure where single user selects or deselects features (Junior et al., 2011). However, it is observed that in real projects, product lines can contain up to 10,000 features (Batory et al., 2006). In such a case, the configuration process becomes an arduous task. Potentially, the larger the size of the feature model, the higher the number of constraints. These constraints define dependencies between features that should be carefully respected to efficiently derive the desired product. Moreover, features have to be compatible with each other. Otherwise, feature interaction issues could arise and affect the product, leading to unexpected behaviour. According to Apel et al. (2013), the feature interaction occurs when a feature behaviour is influenced by the presence of another features. Feature interaction may be classified according to the order reflecting the number of features involved in the interaction, and the visibility characterizing the interaction as external if the impact is visible by the user or internal if it is at system level. For a recent compilation on how feature interaction in SPLE is dealt with, the reader may refer to Soares et al. (2018).

Therefore, handling the configuration process collaboratively is of major interest to enhance configuration within SPLE. Collaboration is defined by Roschelle and Teasley (1995) as "a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem". Similarly, within SPLE, collaborative configuration can be defined as a coordinated, synchronous activity where a set of stakeholders share the configuration activities based on their domain of expertise to decide about the set of features of the desired product. As highlighted in Mendonca et al. (2008), a collaborative configuration process consists mainly of three sub-processes, depicted in Fig. 1: role assignment, configuration and conflict management.

1. Configuration role assignment: it consists in specifying, for each stakeholder, the aspect he/she supposed to configure. The assignment strategy is generally handled in clusters representing a particular functionality of the problem domain.
2. Configuration: it consists in selecting the features of the desired product by the involved stakeholders. Stakeholders can

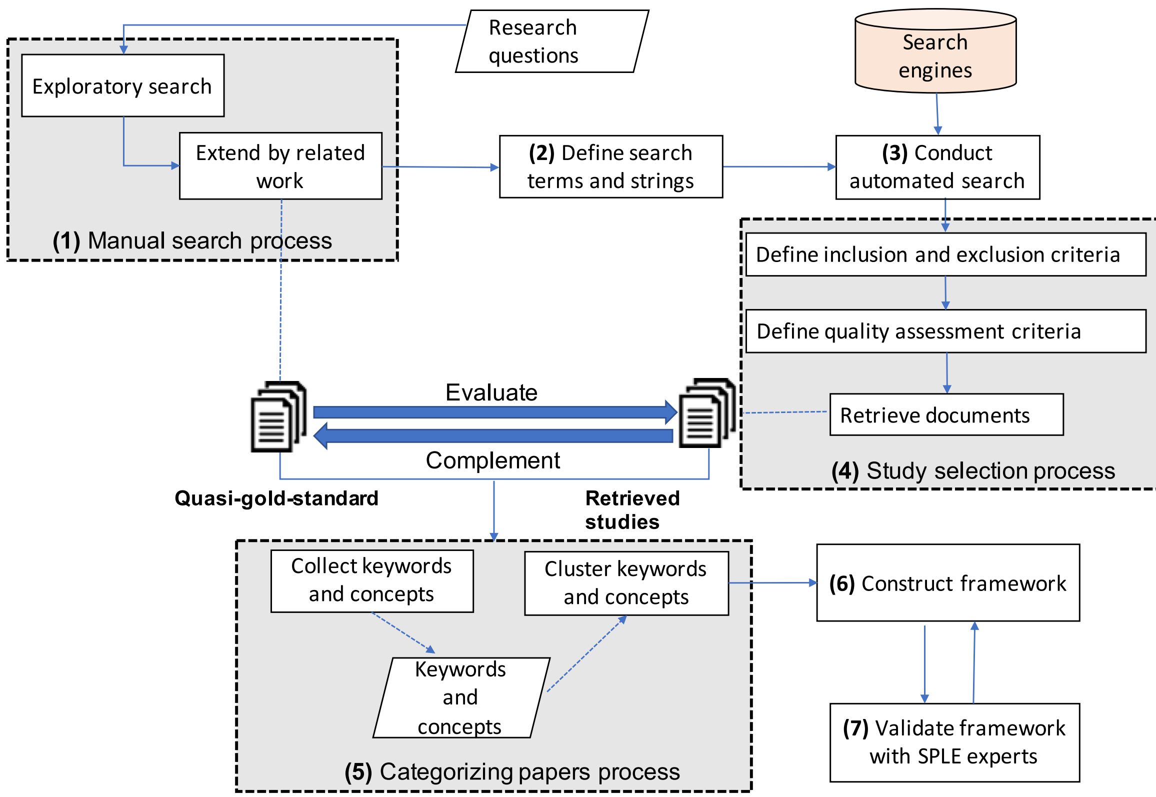

Fig. 2. PL2C framework elaboration process.

share the configuration process according to the role assignment: they can either decide about the selection of the same set of features or each stakeholder decide about a specific set of features.

3. Conflict management: it can be carried out iteratively with the configuration step as conflicts may occur during configuration and have to be managed the time they happen. Another possible alternative is to manage conflicts at the end of the configuration after the stakeholders decide about desired characteristics. This still depends on the collaboration mode.

In the context of a collaborative configuration process, conflict management is of paramount importance. Mendonca et al. (2007) indicate that, when configuring a FM, conflicts may occur when two or more features contain explicit or implicit dependencies that make them rely on each other's decision state. This issue was also discussed by Osman et al. (2009) who outlined the fact that a conflict occurs when two or more configuration decisions assigned to different configuration actors cannot be true at the same time. In practice, collaborative configuration comes up with serious challenges including finding effective means to coordinate configuration tasks and make compromise between all stakeholders requirements in conflict situations. The coordination problem presents a critical issue when configuring FMs with large sizes and complex networks of constraints dependencies. Potentially, the higher the number of constraints, the higher the effort required to put in place effective strategies for conflicts resolution is. Also, some technical issues can make collaborative configuration particularly challenging when involved people are distributed across different space and time dimensions. Therefore, aspects such as communication and group awareness become relevant in order to minimize decisions conflicts and facilitate work coordination.

3. Review approach

In order to elaborate PL2C framework, we carried out a SMS with the identified research questions. The purpose of a SMS is to investigate the literature on a field of particular interest to determine the nature, scope and number of published primary studies (Petersen et al., 2008). It facilitates to obtain a broader view of wide and often poorly-defined research areas (Petersen et al., 2008).

The PL2C framework elaboration process, depicted in Fig. 2, consists of seven sub-processes: (1) manual search, (2) search terms and strings, (3) automated search, (4) study selection, (5) categorizing papers, (6) framework construction, and (7) framework validation. The process was carried out with respect to Petersen et al. (2015).

3.1. Manual search

Manual search sub-process consists in applying a snowballing process to a start set of studies composed of papers describing the first different approaches proposed by some known authors in the field, namely [S1, S3, S4, S11]. It was conducted in two steps: (i) exploratory search in which a forward snowballing was applied. An initial collection of 14 publications was obtained in this step after following references and links to citing publications. (ii) extension by related work in which a backward snowballing was applied on the initial collection of publications by scanning their references and picking out publications relevant to this study. This resulted in additional 8 publications [S9, S10, S20, S21, S22, S23, S25, S31]. In order to avoid redundancy, non-peer reviewed publications, such as technical reports, books and workshop descriptions were not included in the set of retained studies. The results from manual search were used for establishing a quasi-gold standard (QGS), which is a set of known studies representing the main con-

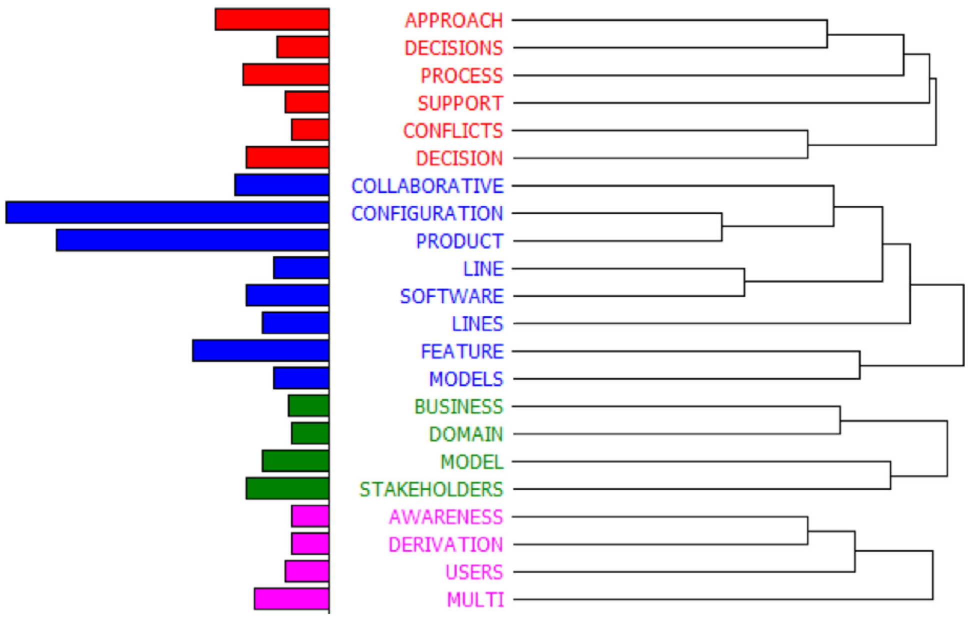

Fig. 3. Clustering result of high frequency terms.

Table 1
Group of terms.

Group	Term	Subject
1	Product line(s)/software product line(s), multi product line(s)	Application domain
2	Feature model(s), collaborative, configuration, derivation, business, process	Specific process
3	Stakeholders/users, multi	Collaboration context
4	Approach, awareness, decision(s), support, conflicts	Conflict resolution mechanism

tributions carried in the research domain (Zhang and Babar, 2009). The QGS was then used to elicit the search strings for automated search.

3.2. Search terms and strings

To make sure that all works related to collaborative configuration of product lines were explored, we conducted an automated search based on terms and strings objectively elicited from the set of QGS. In the literature, search terms is a crucial step in the process of systematic mapping study. It consists on eliciting domain relative terms to retrieve relevant studies (Zhang and Babar, 2009).

We applied search terms process on the set of QGS to identify the most frequently occurring words or phrases in relation with collaborative configuration. Search terms elicitation is done using text mining to statistically analyze the most frequently occurring words. To do so, we imported the title-abstract-keyword segment of each paper under QDA Miner and WordStat[1] which are analysis tools that can not only determine the most frequent terms but also reveal the underlying relationship among these terms. We chose the term frequency (TF) and inverse document frequency (IDF) using WordStat. The Jaccard's similarity coefficient allows to determine the terms importance by comparing the similarity and diversity of the imported segments of QGS. Fig. 3 shows clusters of terms that were derived with high frequency and high Jaccard's coefficient. Colors represent the set of terms strongly linked to each other.

Generally, we can divide these terms into several groups which have a definite subject (c.f. Table 1). However, despite their low frequency, some words are closely related to collaborative configuration of product lines, e.g coordination, resolution and detection. To expand the coverage of search results, we added these terms to the set of elicited terms as complement. Moreover, synonyms of the elicited terms, e.g. stakeholders and users, decision or decisions, model or models were considered in the final search strings. Finally, each group of terms defining the different subjects has been used to derive one or more of the search strings presented in Table 2. In fact, the group of terms presenting the application domain has been considered in all the derived search strings, the second group of terms has been used to formulate the first search string (S1), the third group of terms to formulate the second search string (S2) and the last one, to formulate the third and the last search string (S3, S4).

3.3. Automated search

To conduct the automated search, a set of resources was selected among well known and most common digital libraries and scientific databases used in published SMSs according to Petersen et al. (2015) guidelines namely, IEEE Xplore, ACM DL, Science Direct, Springer, Scopus and Web of science. The first author performed a search based on the derived search strings (c.f. Table 2) using search engines provided by these resources. Results were then checked by the second author.

After eliminating disagreement about considering or not some papers, results of automated search are recorded as depicted in Table 3. Column 2 gives the number of studies returned for each search string. Column 3 shows the total number of papers per search engine. Column 4 represents the number of retained studies after eliminating the duplication per search engine.

[1] http://provalisresearch.com/products.

Table 2
Derived search strings.

No	Configuration process	Search String
S1	Process nature	((software product line **OR** multiple product line) **AND** (configuration **OR** derivation)) **AND** (collaborative process **OR** collaboration process **OR** process collaboration).
S2	Multi user involvement	((software product line **OR** multiple product line) **AND** (configuration **OR** derivation)) **AND** (stakeholders **OR** users **OR** multiple stakeholders **OR** multiple users).
S3	Conflict resolution	((software product line **OR** multiple product line) **AND** (configuration **OR** derivation)) **AND**(conflict resolution **OR** conflict detection **OR** resolution of conflicts **OR** detection of conflicts).
S4	Process coordination	((software product line **OR** multiple product line) **AND** (configuration **OR** derivation)) **AND** (coordination of decisions **OR** decision coordination **OR** supporting awareness **OR** awareness support **OR** support of awareness).

Table 3
Results of automated search.

Search engine	Number of found papers				Total	First round of papers selection
	S1	S2	S3	S4		
IEEE Xplore	29	10	0	1	40	14
ACM DL	41	15	23	9	88	14
Science Direct	5	5	0	3	13	3
Springer	15	10	4	8	37	5
Scopus	9	14	5	14	42	19
Web of Science	6	8	0	4	18	11

Table 4
List of inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
IC1. Research papers from 2005 to 2018 **IC2.** All research works focusing on collaborative configuration of product lines based on the title, keywords and abstract of the papers	**EC1.** All research studies that are not written in English **EC2.** Duplicate papers from different scientific databases: excluding multiple copies of the same study **EC3.** All papers which are not peer reviewed (abstract, poster, proposal, technical report, thesis)

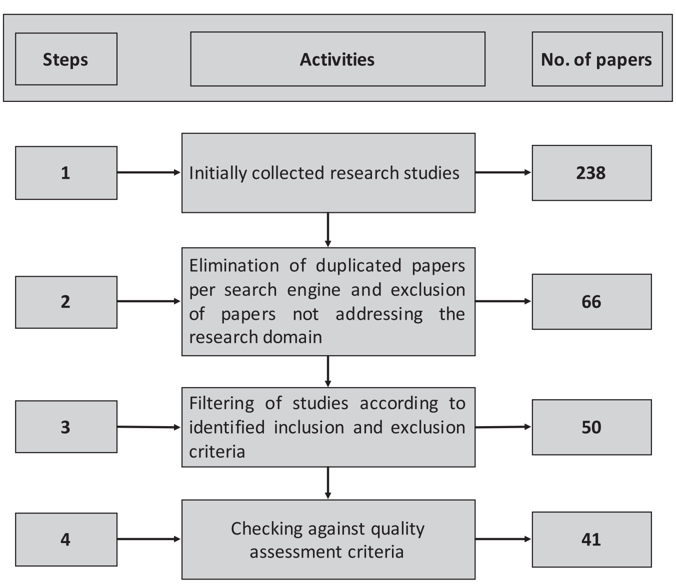

Fig. 4. Steps of document retrieval process.

3.4. Study selection

Study selection sub-process aims at identifying the most relevant studies to product line collaborative configuration domain. Thus, the studies resulted from the automated search were subject to close scrutiny. Fig. 4 illustrates the study retrievement process of this SMS, which consists of four steps: At the first step, we collected 238 probable research. During the second step, duplicated papers per search engine and studies that do not address our research domain were discarded. 66 out of 238 papers have been selected in this step. During the third step, studies were filtered according to identified inclusion and exclusion criteria presented in Table 4. The considered studies are those that were published between 2005 and 2018 (IC1). Actually, we collected papers from 2005 as the first approach in the field has been proposed by Czarnecki in 2005. Obviously, any retained study had to have a clear focus on collaborative configuration of product lines, determined at this stage based on title, abstract and keywords (IC2). However, we note that when the criteria is not certainly satisfied, the research work was considered in order to not miss a relevant study. The final decision of its inclusion was postponed while assessing it against quality criteria. Furthermore, papers that are not written in English (EC1) or duplicated from different databases (EC2) or non peer-reviewed (EC3) were excluded. As for extended studies, they were included as they may contain additional information characterizing the collaborative configuration of product lines.

At the last step, the set of papers retrieved from the previous one (50 papers) was checked against quality assessment criteria presented in Table 5. For each quality question, three answers were assigned: “yes”, “partially”, and “no”. Each study was checked against these criteria. If a study has “yes” as answer, then 1 is assigned to it, if it has “partially”, 0.5 is assigned to it, and a 0 is given to a study that received “no” as answer. Criterion Q1 ensures that the paper deals with any subject related to collaborative configuration of product lines and thus has a suitable context. On top of that, criterion Q2 ensures that the paper potentially answers at least one of the research questions (e.g papers presenting quick overviews, comparative analysis approaches). Criterion Q3 demands that concrete collaborative configuration practices have been fully or partly described. Q3 is added to ensure that works that meet Q2 through answering only RQ1 actually propose collaborative configuration approaches or deal with one of collabora-

Table 5
Quality assessment criteria.

Criteria	Question
Q1	Does the study focus on collaborative configuration of SPLE domain?
Q2	Does the study include the potential answers to research questions?
Q3	Does the study refer to concrete collaborative configuration practices and not just deal broadly with it?
Q4	Is the objective of the study clear?
Q5	Does the study illustrate some collaborative configuration main characteristics ?
Q6	Does the study report original results that have not been published elsewhere?

tive configuration steps. Through criterion Q6, we include in our study extended works if they are presenting novelty compared to the original ones.

The quality assessment was carried by the first author by precisely studying the title, abstracts, and contents of each paper. Then, the obtained quality scores results have been reviewed by the other authors. To make sure of quality assessment findings reliability, only studies with a score equal or greater than 3 were included, which is half of the total points corresponding to the 6 quality criteria. As result, 41[2] out of 238 research studies were selected as final retrieved studies to the research domain.

In this SMS, data were extracted based on the RQs of this work. Each identified study was carefully analyzed to obtain suitable information that can be used to answer the defined RQ. The research studies that highlight information characterizing collaborative configuration of product lines were collected and carefully studied to answer RQ1. Then, the collected studies have been studied in depth to elicit concepts by following a systematic process called “keywording”. Details about this process are given in the next section. Afterward, the PL2C framework has been built upon the extracted concepts. To answer RQ2, the different collected primary studies have been analyzed through positioning in the framework. RQ3 has been answered based on the research studies analysis, where the challenges and current issues of the domain have been identified.

3.5. Categorizing papers

To efficiently elicit concepts related to PL2C framework, we followed a systematic “keywording ” (Petersen et al., 2008) which is a concept study process that helps define classification framework so that it takes all the concepts of retrieved studies into account. This process has been adopted in several papers proposing classification frameworks such as Franzago et al. (2018). Generally, during this process, studies are screened in order to retrieve an overview of the area; in particular, frequently discussed challenges, commonly used classifications and important keywords. As shown in Fig. 2, the keywording process consists of two steps:

1. *Collect keywords and concepts:* keywords and concepts have been identified by reading each primary study with a special core to sections containing terms identified during the search terms process. When all primary studies have been analyzed, all keywords and concepts were combined to clearly identify the context, nature, and contribution of the research. This step output is the set of concepts deduced from the primary studies.
2. *Cluster keywords and concepts:* once keywords and concepts extracted, a clustering operation has been performed on them in order to have a set of representative clusters of keywords. We identified the clusters according to four dimensions: collaboration, purpose, process and tool. These dimensions were chosen as they cover the set of needed information to characterize collaborative configuration within SPLE. Each dimension is further characterized by facets that help understanding and classifying different aspects of collaborative configuration. Faceted classification is based on defining attribute classes that can be instantiated with different terms, as initially proposed by Prieto-Diaz and Freeman (1987) to classify reusable components. Therefore, each cluster represents one of the facets under a specific dimension of our classification. After the clusterization step, keywords and concepts within a cluster were structured in terms of facets and attributes.

3.6. Framework construction

The structuring of PL2C framework was performed by two authors, and the results were double-checked by the two others. The output of this sub-process is the finalized classification framework containing all the concepts that were identified earlier and criteria categorized into dimensions and facets representing a specific aspect of collaborative configuration of product lines. Several iterations over intermediate versions of PL2C framework were required to provide a framework that is as well-defined and as comprehensive as possible. During each iteration, PL2C framework was reviewed by two of the authors who have more than ten years of experience on SPLE, and each disagreement was discussed and resolved. At the end of PL2C framework construction process only sufficiently discriminating concerns and criteria were kept.

3.7. Framework validation

The validation of the PL2C framework is assessed in two steps. (1) Conduction of systematic mapping study to collect information characterizing the collaborative configuration in SPLE domain. The set of keywords and concepts extracted from primary studies have been used to construct the framework and evidence his completeness. (2) Classification of all found primary studies using the framework to illustrate its usefulness. During this step, the first author of this paper read the full text of each paper and extracted its data according to the classification framework with the support of the other co-authors. Details of the full analysis are given in Section 6.

4. Mapping results

As aforementioned, 41[3] research papers were selected as primary studies to be within the scope of this work. Fig. 5 shows that 10 research papers among the primary studies were published in journals; 29 research papers were presented in conferences and

[2] The result of the quality score for each selected study is available at: https://bit.ly/31TfgE2 (Sheet 2).

[3] The list of included studies is available at: http://bit.ly/30vmtsh (Sheet 1).

Table 6
Primary studies venues and identification step.

Venue	Manual search	Automated search	Total
List of conferences			
International Symposium on Object-Oriented Programming Systems, Languages and Application (OOPSLA)		S2	1
Hawaii International Conference on System Sciences (HICSS)	S3		1
ACM Symposium on Applied Computing (SAC)	S4	S36	2
IEEE International Conference on Requirements Engineering (RE)	S6		1
International Conference on Industrial Engineering and Engineering Management (IEEM)		S7	1
International Conference on Systems and Software Product Line (SPLC)	S9, S10, S14, S16, S20, S27	S18, S33, S35	9
International Conference on Requirements Engineering: Foundation for Software Quality (REFSQ)	S11	S26	2
International Workshop on Automated Configuration and Tailoring of Application (ACoTA)	S12		1
International Conference on Information Management and Engineering (ICIME)		S13	1
International Conference on Automated Software Engineering (ASE)		S15	1
IberoAmerican Conference on Software Engineering (CIBSE)	S17		1
International Workshop on Variability Modelling of Software-intensive Systems (VAMOS)	S19		1
Asia Pacific Conference on Software Engineering (APSEC)	S21, S22		2
IEEE International Conference on Services Computing (SCC)	S23		1
International Conference on Software Engineering and Knowledge Engineering (SEKE)		S29	1
International Conference on Software Engineering (ICSE)	S38	S30, S39	3
International Conference on Software Language Engineering (SLE)		S32	1
International Workshop on the Move to Meaningful Internet Systems (OTM)		S37	1
List of journals			
Software Process: Improvement and Practice	S1		1
Journal of Software (JSW)	S5		1
Science of Computer Programming journal	S8		1
Journal of China Universities of Posts and Telecommunication (JCUPT)		S24	1
Software and Systems Modeling journal (SoSyM)	S25		1
Requirements Engineering journal		S28	1
Information and Software Technology journal (IST)	S31		1
Computer and Industrial Engineering journal (CAIE)		S34	1
Journal of Systems and Software (JSS)		S40	1
Journal of Computer Languages, Systems and Structures		S41	1
Total of papers	22	19	41

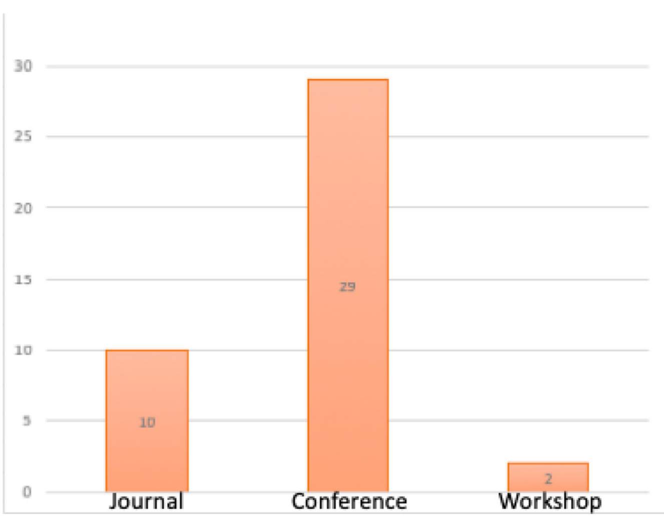

Fig. 5. Primary studies categorized by venue type.

2 research papers were presented in workshops. Studies are summarized according to their venues and the research step in which they were collected in Table 6. We notice that around one third of conference papers was published in SPLC which is specialized on SPLE domain.

Furthermore, Fig. 6 gives more details by presenting the publication years and types of the primary studies. As depicted in the histogram, the number of publications has increased from 2010 and almost 50% of papers were published between 2010 and 2013. We notice that 2010 had the highest number of published papers. In fact, from the first proposed approach in the field (2005) to 2007 only one paper per year was published. For the two years 2008 and 2009 two papers per year were published. The following years starting from 2010 witnessed the growth of interest in collaborative configuration within SPLE which can be deduced through the publications number.

Fig. 7 depicts a map of publications over our defined classification criteria. The size of each bubble represents the number of publications in the corresponding category pair. Research focus is shown on the Y axis, contribution type is shown on the right X axis, and research type is shown on the left X axis.

For the research type, we adopted the classification approach described by Wieringa et al. (2006). This classification has been also used by Petersen et al. (2008). Research type is categorized as follows:

- *Experience papers:* papers explaining what and how something has been done in practice. It has to be the personal experience of the author.
- *Philosophical papers:* papers sketching a new way of looking at existing things by structuring the field in form of a taxonomy or conceptual framework.

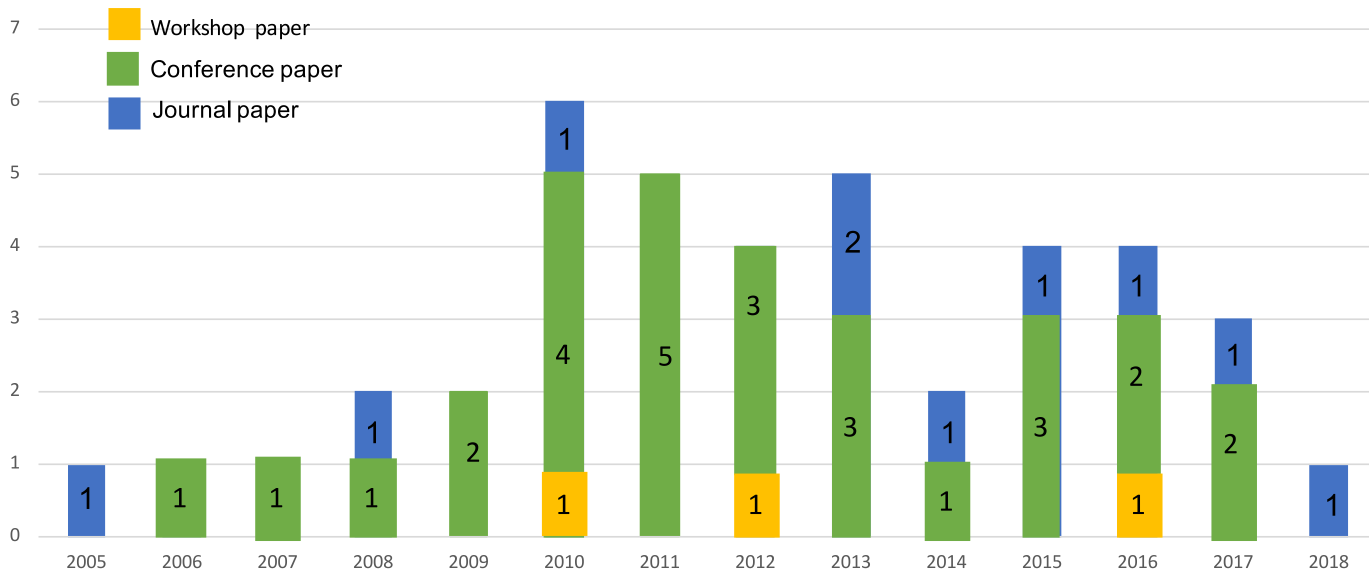

Fig. 6. Primary studies distribution per year and publication types.

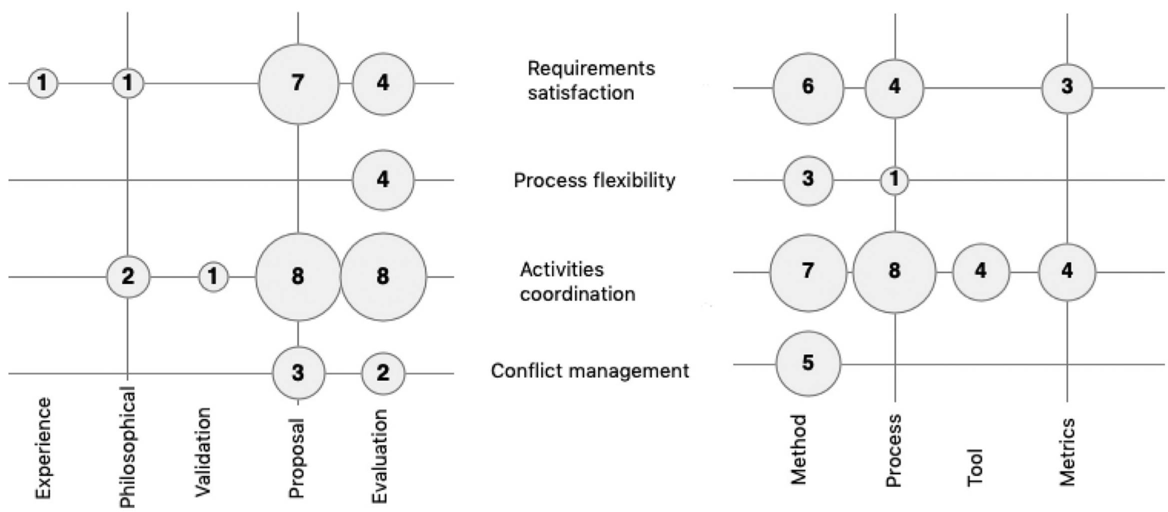

Fig. 7. Bubble chart map of research focus over research and contribution types.

– *Validation research:* papers investigating novel techniques that have not yet been implemented in practice. Techniques used are for example experiments, i.e., work done in the lab.
– *Solution proposal:* papers proposing solution for a problem. The solution can be either novel or a significant extension of an existing technique. The potential benefits and the applicability of the solution is shown by a small example or a good line of argumentation.
– *Evaluation research:* papers presenting implementation of practical techniques along with their evaluation. That means it is shown how the technique is implemented in practice (solution implementation) and what are the consequences of the implementation in terms of benefits and drawbacks (implementation evaluation). This also includes to identify problems in industry.

Research focus is classified into four main categories: (1) *Requirements satisfaction:* approaches considering the satisfaction of stakeholders' requirements. (2) *Process flexibility:* approaches proposing a mechanisms that are used to ensure the flexibility of collaborative configuration process. (3) *Activities coordination:* approaches that are used for coordinating configuration activities. (4) *Conflict management:* strategies used for the purpose of resolving conflicts in the collaborative configuration approaches.

Finally, contribution type comprises four main categories: (1) *Method:* description of how to carry out a specific step of collaborative configuration (conflict resolution for instance). (2) *Process:* research that deals with the collaborative configuration process. (3) *Tool:* any tool designed to support collaborative configuration. (4) *Metrics:* metrics that are used for the purposes of configuration activities assignment, configuration, conflict resolution or satisfaction measurement.

Some articles involve more than one contribution type. For example, (Junior et al., 2011) involves both method and tool contribution types and hence is considered in each one of them. However, each paper is classified under only one research type: the one to which we feel the study belongs the most.

With regard to research type, the majority of the articles are of the evaluation research type (43.9%) and solution proposal (43.9%) compared with the small number of studies that were philosophical (7.3%), experience articles (2.4%) and validation research (2.4%). A large majority of papers (75.6%) were about methods (46.3%) and

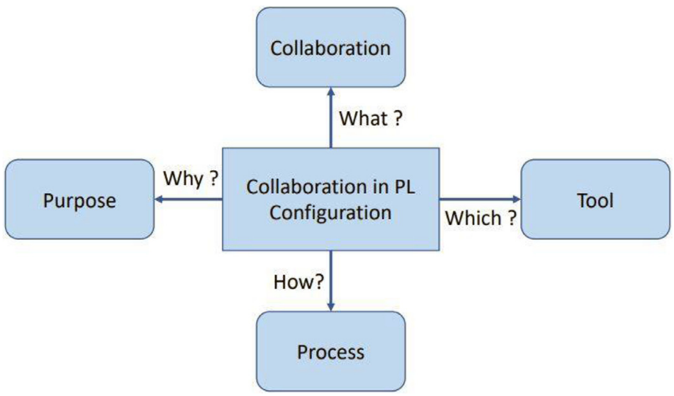

Fig. 8. PL2C framework for collaborative configuration approaches in SPLE.

processes (29.3%), and only 1/4 of studies is about metrics (17.1%) and tools (7.3%). Activities coordination (50%) was the largest research focus area, followed by requirements satisfaction (29.5%).

A very small number of the studies focused on conflict management (11.4%), and process flexibility (9.1%), with a combined total of 20.5%.

Overall, the proposal and evaluation of activities coordination methods and processes currently dominate the body of the literature on collaborative configuration of product lines.

The different research focus have been studied in depth and considered in our framework elaboration, this is discussed in more detail in the following section.

5. The PL2C framework

The main objective of this paper is the elaboration of framework to provide a generic and conceptual artifact containing knowledge about collaborative configuration within SPLE domain. This framework will provide support for classifying and analyzing existing and future approaches that address product line collaborative configuration. This should help researchers and practitioners in better scoping their own contributions or understanding existing ones.

To elaborate this framework, we defined the three research questions highlighted at the beginning of the paper which are:

- *RQ1: What are the main characteristics of state-of-the-art approaches on the field of collaborative product line configuration?* PL2C framework is composed of four dimensions as illustrated in Fig. 8. Features extracted from the retrieved primary studies have been clustered according to these dimensions. We have chosen these dimensions as they cover the set of needed information to characterize collaborative configuration within SPLE. The four dimensions are:
  - Purpose dimension: This dimension discusses the “why” angle of the collaborative configuration approach. In other words, it explains the objectives of collaborative configuration approaches.
  - Collaboration dimension: This dimension discusses the “what” aspect in the framework. Defining what is collaboration in product line configuration and what it is all about (e.g. collaboration mode, interaction and collaboration level).
  - Process dimension: This dimension discusses how the configuration process is carried out.
  - Tool dimension: A tool, or a combination of tools, is considered to be the instrument which is necessary to complete the purpose of the task based on the method applied.

  Dimensions are characterized by sets of facets that help understand and classify different aspects of collaborative configuration. As pointed in Al-Abri et al. (2017), faceted classification is based on defining attribute classes that can be instantiated with different terms. Facets are considered as viewpoints suitable to characterize configuration approach through a set of relevant attributes. These attributes are described by a set of values for measuring and positioning the observed aspect based on the extracted data. Some facets may depend on other facets belonging to the same dimension across values that an attribute may have.
- *RQ2: What are the strengths and weaknesses revealed from the comparative analysis of the existing collaborative configuration approaches?* As dimensions are defined with multiple facets, the characteristics of each approach, including strengths and weaknesses can be identified through the positioning of existing approaches in the framework.
- *RQ3: What are the major challenges of collaborative configuration in the field of SPLE?* Likewise, shortcomings and challenges can be identified through the positioning analysis of the different approaches.

5.1. Purpose dimension

Purposes can be discussed based on varied facets (c.f. Fig. 9) which are classified according to the role the collaborative configuration aims to play.

5.1.1. Principle facet

The studied approaches show that decision making during configuration can be: either *shared* between two or more stakeholders (Mendonca et al., 2008) where the selection of feature is decided by more than one stakeholder, or each set of decisions is assigned to a *single* stakeholder according to his/her expertise (Czarnecki et al., 2005; Mendonca et al., 2007; 2008; Hubaux. et al., 2010).

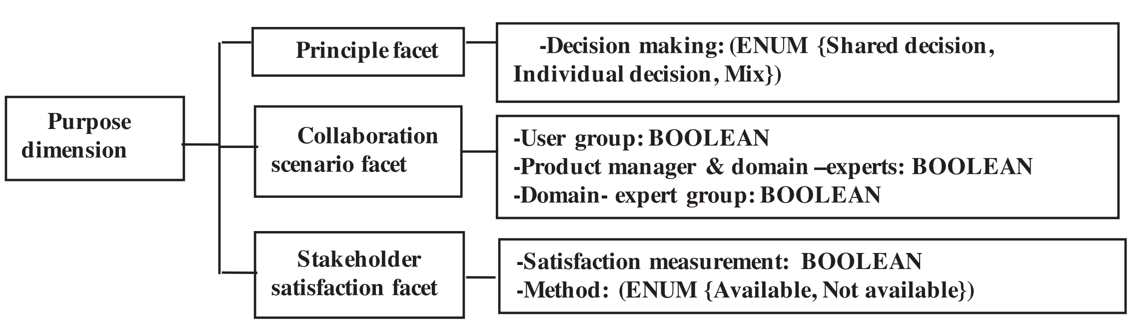

Fig. 9. Purpose dimension overview.

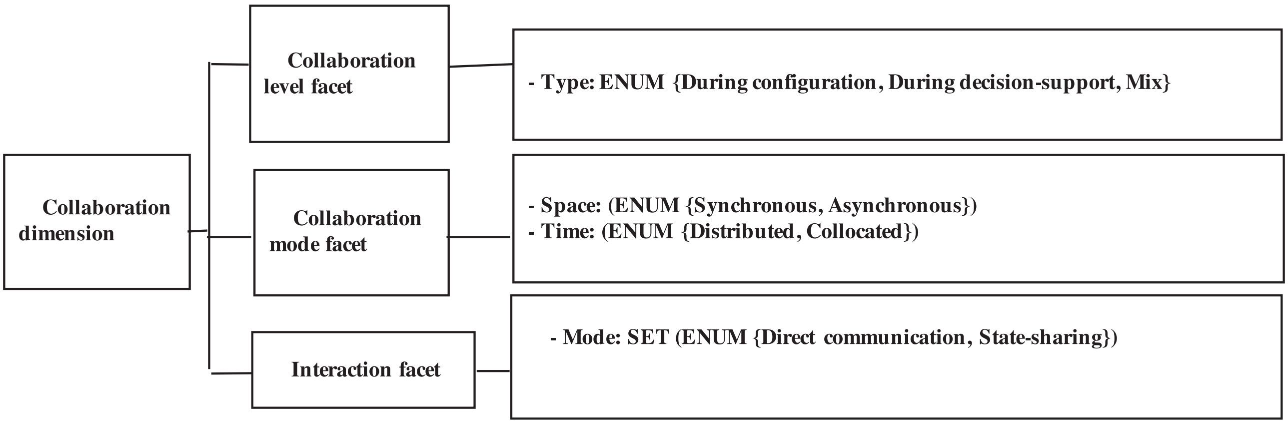

Fig. 10. Collaboration dimension overview.

The *principle* facet is presented with a *decision-making* attribute as follows:

Decision making: ENUM {Shared decision, Individual decision, Mix}.

5.1.2. Collaboration scenario facet

Collaborative configuration can be carried out in different scenarios according to the involved team category (*end users* and/or *domain experts*). In fact, a collaborative configuration approach can be designed to allow a group of users collaboratively expressing their requirements towards a desired product (e.g. a group of friends want to buy a tablet Stein et al., 2014). Moreover, a collaborative configuration approach can be designed to be adopted in a real industrial project (e.g. car manufacturing) where configuration process is carried out by a group of domain-experts. The different scenarios are presented as following:

- *User group*: The collaborative configuration approach is designed to allow end users who do not have a background in SPLE domain (not expert) in expressing their requirements towards the desired product such as the approach proposed by Dou et al. (2016).
- *Product manager and domain-experts*: collaborative configuration may be shared between a product manager who decides about product features at a high-level and domain-experts who decide about product features at a technical level, as it is the case in industrial context (Mendonca et al., 2008).
- *Domain-expert group*: in this collaboration scenario, there is no role hierarchy, where configuration activities are fairly shared between stakeholders according to expertise level as it is the case in the approach proposed by Czarnecki et al. (2005).

In some cases, we can find approaches that are designed to support both user group and domain-expert group where end users express their requirements and domain-experts consider these choices in configuring the desired product (e.g. Bingliang et al., 2010).

The different collaboration scenarios presented above are captured by the following three Boolean attributes: *User group, Product manager and domain-experts,* and *Domain-expert group*.

5.1.3. Stakeholder satisfaction facet

Stakeholder satisfaction is of paramount importance when collaboratively configuring a product within SPLE. It can be ensured by considering preferences of stakeholders in deriving the desired product. Therefore, preferences have been differently considered in the existing collaborative configuration approaches. For example, preferences can be expressed in terms of hard and soft requirements as proposed by Bagheri et al. (2010), or in terms of functional and non-functional requirements as proposed by Soltani et al. (2012). Satisfaction can also be ensured during conflict resolution by finding the good compromise between the different requirements of stakeholders as proposed by Stein et al. (2014) and Ochoa et al. (2015).

The satisfaction measurement is captured by the Boolean *Satisfaction measurement* attribute, and by the*Method* attribute:

Method: ENUM {Available, Not available}.

5.2. Collaboration dimension

This dimension discusses the “what” aspect in the framework. Defining what is collaboration in product line configuration and what it is all about (e.g. collaboration mode, interaction and collaboration level). An overview of collaboration facets is depicted in Fig. 10.

5.2.1. Collaboration level facet

According to the studied approaches, collaboration can be present at two different moments: (1) *during configuration*, where stakeholders actively share the configuration activities (Mendonca et al., 2008). They can either decide about the selection of the same set of features or each stakeholder decide about a specific set of features according to role assignment process. (2) *during decision-support*, where collaboration-based recommendation techniques (i.e., collaborative filtering Schafer et al., 2007) are used to guide stakeholders in making the good configuration decision by recommending features for example (Pereira, 2017). It is possible that a configuration approach encompasses the two collaboration levels such as Mendonca et al. (2008) and Junior et al. (2011). The collaboration level facet is characterized with a *type* attribute as follows:

Type: ENUM {During configuration, During decision-support, Mix}.

5.2.2. Collaboration mode facet

Collaboration requires a collaboration space as an environment to facilitate the collaborative process. The characteristics and nature of this space depend on the form of collaboration. There are two forms of collaboration based on the space: (1)*collocated* that occurs in the same place as the case in the approaches proposed by Mendonca et al. (2007) and Stein et al. (2014) and (2) *distributed* that occurs in different places. Several approaches proposed different methods to improve awareness and ensure global consistency when the configuration is geographically distributed such as Junior et al. (2011) and Holl et al. (2012). There are also two forms of collaboration based on the time. It can be either

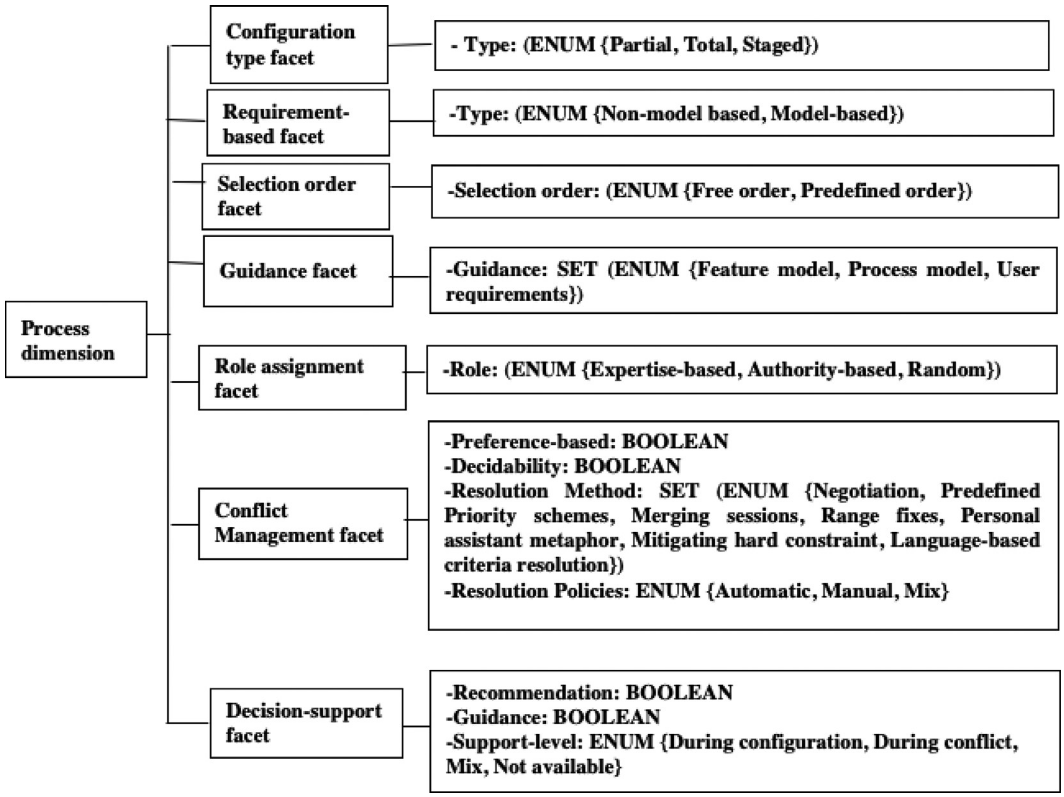

Fig. 11. Process dimension overview.

carried out in real time (*synchronous*) where stakeholders configure the pro same time (e.g. Bingliang et al., 2010) or in different times (*asynchronous*) (e.g. Hubaux. et al., 2010) where the configuration states are communicated to ensure global consistency (Al-Abri et al., 2017; Camarinha-Matos and Afsarmanesh, 2008).

Time: ENUM {Synchronous, Asynchronous}.

Space: ENUM {Distributed, Collocated}.

5.2.3. Interaction facet

During the configuration process, interaction is mainly required between stakeholders. Stakeholders share configuration information to improve awareness and ensure global state coherence during configuration. Awareness improvement has been mainly addressed in the context of Multi Product Line configuration where some approaches such as Rabiser et al. (2010b) and Holl et al. (2012) proposed a shared repository that allows stakeholders to share their decisions in order to be aware about the decisions of other stakeholders. In some cases, stakeholders also need to communicate when a conflict arises (Mendonca et al., 2008). The interaction can be ensured with different means as characterized with the following attribute:

Mode: SET (ENUM { Direct communication, State-sharing }).

5.3. Process dimension

This dimension discusses how the configuration process is carried out. It addresses seven facets as depicted in Fig. 11: *configuration type, level, flexibility, guidance, role assignment, conflict management* and *decision-support*.

5.3.1. Configuration type facet

In the studied approaches, different configuration types have been outlined: the *partial configuration*, the *total configuration* and the *staged* one. In *partial configuration*, each stakeholder configures a part of the product such as in Mendonca et al. (2008). In *total configuration*, each stakeholder configures the whole product then the different configurations are checked and merged according to stakeholders' requirements (Stein et al., 2014). In *staged configuration*, as pointed by Czarnecki et al. (2005), the configuration is refined from stage to another through a set of specializations progressively applied on the feature model. The configuration type facet is characterized with a *Type* attribute as follows:

Type: ENUM {partial, total, staged}.

5.3.2. Requirement-based facet

The configuration process can mainly be carried out at two different levels: the intentional and the operational level. At the intentional level, stakeholders express their requirements regarding the desired product without being constrained to a model structure (e.g. feature model). At the intentional level, the configuration is *non-model based*. One of the first works proposing a non-model based configuration is Djebbi and Salinesi (2007) where stakeholders' requirements are matched with product line requirements to derive a consistent configuration with respect to stakeholders' priorities and company's constraints. Different collaborative configuration approaches have adopted the non-model based configuration principle such as Chen et al. (2009) and Dou et al. (2016). As for the operational level, the configuration is *model-based* where requirements are mapped with the corresponding FM to see which features meet them. At this level, requirements are translated and directly considered as decisions of selecting/deselecting features from the FM. Most of the proposals found in the literature such as (Mendonca et al., 2007), Mendonca et al. (2008), Rabiser et al. (2009), Hubaux. et al. (2010), Junior et al. (2011), Holl et al. (2012), Stein et al. (2014) and Pereira (2017) have proposed model-based configuration approach.

The requirement-based facet is characterized with a *Type* attribute as follows:

Type: (ENUM {Non-model based, Model-based}).

5.3.3. Selection order facet

Flexibility is widely recognized as one of the most important dimensions of a successful manufacturing strategy. As pointed by de Groote (1994) “A particular technology is said to be more flexible than another if an increase in the diversity of the environment yields a more desirable change in performance (i.e. higher increase or lower decrease) than the change that would obtain with the other technology under the same conditions”. In a flexible configuration process (e.g. Junior et al., 2011; Stein et al., 2014), stakeholders can *freely* express their requirements without being constrained to prior decisions when making new choices. When the configuration relies on pre-designed process with a *predefined order* (e.g. Mendonca et al., 2007; Mendonca et al., 2008), decisions made by some stakeholders constrain posterior ones made by other stakeholders. In such a case, backtracking may be occasionally required to cope with constrained decisions, which makes it difficult to reach a valid configuration agreed by all stakeholders.

Selection order: ENUM {Free order, Predefined order}.

5.3.4. Guidance facet

The configuration process can be guided differently depending on the product line model, and on the requirements of the stakeholders. Usually, configuration is driven by the *feature model* as it is broken down into different insulated modules (also called views) and each stakeholder deals with the configuration of a module based on his/her expertise domain while respecting the domain constraints (Hubaux. et al., 2010). In some cases, the configuration can also be driven by a *process model* describing the configuration process that means role assignment, configuration order, priority schema (Mendonca et al., 2007). Moreover, configuration processes can be driven by stakeholder requirements independently of the FM hierarchy by scheduling the different configuration activities according to the importance of *requirements*. The guidance facet is characterized by the guidance attribute defined as follows:

Guidance: SET (ENUM {Feature model, Process model, User requirements}).

5.3.5. Role assignment facet

The assignment process takes into consideration two criteria: authority and knowledge of the domain (Czarnecki et al., 2005; Mendonca et al., 2008). Thus, the leader of the process (e.g. the product manager) configures the product at high-level then other roles are assigned according to the expertise of stakeholders (Mendonca et al., 2007). A *random* assignment is also possible in some cases (Stein et al., 2014), according to the nature of persons involved (e.g. an academic prototype tested by a group of students, or a commercial online configuration tool used by a group of customers). The Role assignment facet is characterized by an attribute called *Role*:

Role: ENUM {Expertise-based, Authority-based, Random}.

5.3.6. Conflict management facet

During collaborative configuration, causes of conflict range from heterogeneous requirements to divergent points of view regarding how the desired product should be.

During collaborative configuration, conflicts are managed through different *resolution methods* and *policies*. The conflict management facet gives an understanding on how the resolution process is carried out. It addresses the following attributes: *Preference-based, Decidability, Resolution method* and *Resolution policies*.

A conflict resolution strategy cannot be considered effective if it does not take into account *preferences* of the different stakeholders and try to find a compromise between the most of them Stein et al. (2014). Moreover, resolution strategy should also be *decidable* in the sense that it must guarantee a finite state where conflicts are always resolved (Ochoa et al., 2015). The nature of resolution strategy is characterized through the following attributes:

Preference-based: BOOLEAN.

Decidability: BOOLEAN.

Different resolution methods have been proposed for collaborative configuration of product lines. Some works such as Chen et al. (2009) resolve conflicts by inviting stakeholders to *negotiate*. Some workflow-based approaches such as Mendonca et al. (2008) proposed a *merging sessions* method to resolve decision conflicts. During the merge, domain-experts in charge of related configuration decisions reason about potential solutions to the conflict. The merge is required if two or more parallel interdependent configuration sessions contain decisions that together violate global configuration constraints. Other works such in Mendonca et al. (2007), propose a *predefined priority scheme* where conflicts are resolved according to stakeholders' role importance or decision importance. Moreover, we find other resolution methods where a set of correction values called *Range Fixes* are either directly suggested to stakeholders (Rabiser et al., 2009; Xiong et al., 2012) or recommended using a *personal assistant metaphor* (Junior et al., 2011).

Some other approaches were interested in increasing stakeholders satisfaction by proposing preference-based conflict resolution methods. In these methods, preferences are considered in different manners. (1)expressed through soft and *hard constraints* (Stein et al., 2014), during the resolution, hard constraints are mitigated by assigning preference degrees and maintaining the decision with the highest degree of preference expressed, (2) by using *language-based criteria* to consider stakeholders preferences expressed in terms of non-functional properties (Ochoa et al., 2015).

The different collaborative resolution methods presented above are captured by a set of values characterizing the *resolution method* as follows:

Resolution method: SET (ENUM {Negotiation, Predefined priority schemes, Merging sessions, Range fixes, Personal assistant metaphor, Mitigating hard constraint, Language-based criteria resolution}).

These resolution methods can be executed according to different *policies*: (1) conflicts are *manually* resolved where stakeholders are involved in the resolution process either by revising their requirements or by expressing their preferences towards the conflicting ones, (2) conflicts are *automatically* resolved considering a set of criteria such as stakeholders' role importance and requirements importance. In some cases, it is possible to combine both *policies* where stakeholders express their preferences toward conflicting requirements, then a preference-based resolution process is automatically launched.

The resolution policies is characterized with the following attribute:

Resolution policies: ENUM {Automatic, Manual, Mix}.

5.3.7. Decision-support facet

When configuring large feature models, guidance can be useful to support users in decision-making at different levels. Guidance can be ensured by different methods. For example, (Junior et al., 2011) propose an assisted user-guidance method provided by software agents to guide users *during configuration* process. Moreover, recommendation techniques also represent an effective guidance mean: either *during configuration*, where features can be recommended to help stakeholders meeting their requirements (Pereira, 2017), or *during conflict* situations, where alternative feature-selection scenarios can be recommended to stakeholders to guide them in conflict resolution (Xiong et al., 2012). The Decision-support facet is characterized by the following attributes:

Recommendation: BOOLEAN.

Guidance: BOOLEAN.

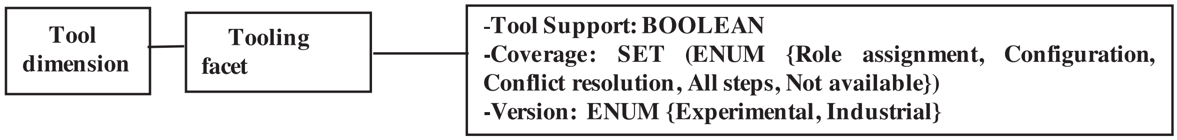

Fig. 12. Tool dimension overview.

Support- level: ENUM {During configuration, During conflict, mix, not available}.

5.4. Tool dimension

The final view in PL2C framework is the tool dimension (c.f. Fig. 12). A tool, or a combination of tools, is considered to be the instrument which is necessary to complete the purpose of the task based on the method applied. According to the studied approaches, some proposals are *not supported* by a configuration tool (Czarnecki et al., 2005; Mendonca et al., 2007). Some others propose a tool that supports a step of the collaborative configuration (e.g. a tool for FM decomposition and*role assignment* Mendonca et al., 2008). Actually, the most of the developed tools mainly support the configuration step (Holl et al., 2012; Soltani et al., 2012). Some tools are still in *experimentation* level (Junior et al., 2011; Stein et al., 2014), other ones are validated within *industrial* case studies and already deployed in some companies (Hubaux. et al., 2010; Rabiser et al., 2010b).

The Tooling facet is characterized with the three following attributes:

Tool Support: BOOLEAN.

Coverage: SET (ENUM {Role assignment, Configuration, Conflict resolution, All steps, Not available}).

Version: ENUM {Experimental, Industrial}.

6. Approaches analysis

According to framework-based positioning of the 41 retrieved studies[4], works can be categorized as follows:

- Studies proposing collaborative approaches that rely on a predefined process in which configuration tasks are coordinated and assigned to expert group where each of them is in charge of configuring a specific module (called view in some papers) of the feature model, such as [S1, S2, S3, S4, S5, S6, S8, S11, S14, S20, S25, S40]. Some of these approaches [S4, S5, S8] permit sharing configuration decision making where a module can be configured by a team and not by only one expert.
- Studies proposing flexible collaborative approaches where configuration is carried out in a free order process without imposing a selection order on stakeholders [S17, S26, S27, S32, S33, S34, S35, S37].
- Studies proposing collaborative approaches that do not provide explicit information about all the collaborative aspects and the selection order during the configuration [S7, S9, S10, S12, S13, S15, S16, S18, S19, S21, S22, S23, S24, S28, S29, S30, S31, S36]. However, each group of these studies has a specific focus on one of the main characteristics of collaborative configuration. For example, [S12, S16, S19, S21, S22, S31] propose methods to ensure configuration consistency and increase awareness during configuration of multi product lines. As for [S7, S9, S10, S13, S15, S18, S23, S24, S28, S29, S30, S36], they propose various solutions permitting the consideration of all stakeholders individual configurations while deriving a valid configuration that better consider their functional and non-functional requirements.
- Studies considering collaboration at a decision support level [S38, S39, S41] where collaborative-based techniques are used to guide users in selecting features during configuration process. Here, the collaborative aspect is approached differently as it consists in learning about relevant features from other users' configurations.

Moreover, according to the reported analysis, it was noticeable that only 14 studies among 41 consider the satisfaction of stakeholders in the different solutions they propose [S9, S10, S13, S15, S18, S23, S24, S27, S28, S29, S32, S34, S36, S37]. These studies aim at improving the satisfaction of stakeholders in two different manners: ***(1)*** by taking into account the preferences of stakeholders during the configuration step. In other words, they consider their functional and non-functional requirements in the final derived configuration [S9, S10, S13, S15, S18, S23, S24, S28, S29, S34, S36]. ***(2)*** by increasing the stakeholders' satisfaction through preference-based strategies for conflict resolution [S27, S32, S37]. However, most of the other 27 studies do not provide information about conflict management, except [S2, S3, S4, S5, S7, S8, S11, S17, S22, S26] that propose resolution strategies without dealing with stakeholders' preferences.

In terms of main results, the focus was generally on analyzing stakeholder' requirements to derive consistent configuration, or on ensuring coordination during the configuration process. The collaboration was more aligned with the two first steps of the collaborative configuration process (role assignment, configuration) than the conflict management (e.g. resolution method or policy).

7. Challenges

According to the full analysis of the 41 retrieved studies, three challenges can be highlighted:

1. *Configuration process coordination:* the coordination represents one of the main challenges of collaborative configuration. The coordination issue can be addressed in two different ways: *(1)* by following a pre-designed configuration process specifying the role and the intervention time of each stakeholder. However, such a method constraint decisions of some stakeholders, hence it limits the configuration process flexibility. (2) by allowing free order configuration process where stakeholders express their requirements separately, then a mapping process is in charge of finding a compromise between the different requirements. Here, more effort is required to ensure the global state consistency. Therefore, awareness and state sharing means have to be set up between the distributed stakeholders.
2. *Conflict management:* this challenge is about providing an effective support for decision conflict resolution. Different methods can be set up to resolve conflicts.*(1) systematic resolution* by prioritizing choices made at early stage. *(2) automatic resolution* by analyzing all stakeholders choices and deriving a consistent configuration regardless of expressed preferences. (3) *manual resolution* through negotia-

[4] The classification of all primay studies is available at: https://bit.ly/31TfgE2 (Sheet 3).

tion of possible alternatives. (4) *preference-based resolution* by considering hard/soft and functional/non-functional requirements in the resolution process.
However, conflict resolution is still challenging whatever the adopted strategy is as it depends on how the found compromise between heterogeneous requirements satisfy the stakeholders in question.

3. *Stakeholders' satisfaction:* It is important to highlight that stakeholders satisfaction should be considered as a key criteria to measure the effectiveness of a collaborative configuration process and a purpose that a collaborative configuration has to reach at first. The satisfaction is quite challenging in front of finding a good compromise between stakeholders' decisions as in the case of total intersection of their hard constraints or when stakeholders share all the configuration decisions space in a order-free process.

8. Related work

The current state-of-the-art research work is limited to elaborating various collaborative configuration approaches without presenting a comprehensive framework that permits understanding the collaborative configuration process, its main characteristics the effectiveness and the limitation of the current dedicated approaches. Thus, there is still little understanding about how collaborative configuration process should be carried out and its steps remain ambiguous. To the best of our knowledge, we are the first to propose a framework capturing the main characteristics of collaborative configuration approaches. The framework gives a"big picture" of the collaboration in product line configuration research area and helps understanding the configuration challenges treated in currently developed product line collaborative configuration approaches in the literature.

The different attributes captured in PL2C framework are inspired from characteristics of both collaborative process and configuration of product lines identified in different previous studies. In fact, several works propose different frameworks. Some of them such as Rolland (1998) and Nurcan (2004) address process engineering and workflow flexibility which give an overview to understand and classify characteristics and issues in the field. Other studies such as (Al-Abri et al., 2017) and Franzago et al. (2018) indirectly address collaborative process through adopting their characteristics to elaborate a comparative framework classifying approaches in different fields. These studies give an overview of the main attributes characterizing a collaborative process regardless the application domain. Another framework has been proposed by Gacita et al. (2019) for the classification of FMs construction approaches. To evidence the framework completeness and assess its usefulness, the different works cited above use the framework to classify approaches identified in the field.

In the context of software product lines engineering, a lot of work was devoted to presenting the most common characteristics of the configuration process and the related challenges especially when facing large-scale product lines such as configuration consistency checking, performance concerns and scalability. These challenges have been identified in different surveys and systematic reviews carried in the field such as Sabin and Weigel (1998), Hubaux and Heymans (2009), Rabiser et al. (2010a), Afzal et al. (2016) and Ochoa et al. (2017).

Mainly, much work has been carried out in the context of feature model analysis and decision support during configuration. Various approaches have been developed to help reduce the complexity of the configuration process by automating the feature model configuration activity (Benavides et al., 2005; Batory et al., 2006) and proposing effective support to manage constraints among features (Pillat et al., 2013; Martinez et al., 2014). Some other approaches proposed using recommendation techniques to guide the user during the configuration process (Mazo et al., 2014; Triki et al., 2014; Pereira et al., 2018). However, these studies do not take into consideration the collaborative aspect of this process that can be more challenging when involving more than one stakeholder.

9. Threats to validity

In this paper, a comparative framework for characterizing collaborative configuration within SPLE is presented. In our study, we achieved such a high level of quality by (i) formalizing our study design into a research protocol (ii) conducting our study by carefully following well-accepted and updated guidelines of SMS (Petersen et al., 2015) and (iii) analyzing and discussing the results of the approaches positioning against the framework.

In the sequel, we detail the main threats to validity related to this work.

- *Research questions.* The goal of this study is to give an overview of product line collaborative configuration field. Therefore, our research questions are relatively general. However, possible more specific questions may be identified to explore in depth the research domain.
- *External validity.* This threat related to external validity consists in having a set of primary studies that is not representative of the whole research on collaborative configuration of product lines. We mitigated this potential threat by following a systematic search process with respect to Petersen et al. (2015) guidelines. The selected studies have been explored in depth. Moreover, defining, iteratively refining and validating the set of the selected criteria contributed to reinforce the external validity of our study.
A further threat related to external validity is associated with gray literature (e.g. white papers, non-reviewed publications or books, etc.) which is not included in our research since we want to focus exclusively on the state of the art presented in high-quality scientific studies.
- *Internal validity.* It refers to the influence of extraneous variables on the design of the study. This potential threat to validity has been mitigated by defining and validating our classification framework by carefully following a well-structured elaboration process (see Section 3). Regarding the validity of the synthesis of collected data, we structured both vertical and horizontal analysis according to collaborative configuration challenges defined through attributes combination so the threats were minimal.
- *Construct validity.* It concerns the validity of extracted data with respect to the research questions. To mitigate this source of threats, we performed an automated search on multiple electronic databases to avoid potential biases due to publishers policies and business concerns. Also, we applied the framework on all the 41 primary studies to give an understanding of how collaborative configuration can be carried out in SPLE. Thus, it allows answering the research questions highlighted in the introduction and making us reasonably confident about our search strategy.
- *Conclusion validity.* It concerns the relationship between the extracted data and the obtained results. Threats to conclusion validity have been mitigated by applying well-assessed research protocol throughout our study. The corresponding process has been formalized and documented, so this study can be replicated by other researchers interested in collaborative configuration of product lines. Moreover, other researchers may identify facets and attributes different from the ones captured in our framework. We mitigated this po-

tential threat by iteratively validating the framework with SPLE experts. During each iteration, the framework was reviewed by two of the authors who have more than ten years of experience on SPLE, and each disagreement was discussed and resolved.

We also performed an evaluation with others researchers who were not involved during the elaboration of the framework. We also avoided to discuss analysis results that may not be directly related to collaborative configuration challenges that we have identified. Therefore, we avoided including any concepts that, since solely extracted from research papers, may not be representative of the product lines collaborative configuration process. Finally, we claim that our framework is extensible and open as it can encompass new concepts (facets and attributes) characterizing new aspects that may be proposed by future collaborative configuration approaches.

10. Conclusion

Our study has shown that no extensive study has been reported so far for comparing and understanding collaborative configuration approaches within SPLE. Hence, this motivated us to explore further the domain by conducting a systematic mapping study. The result of this study has been used to conceptualize an analysis framework for work in the area of product line collaborative configuration, and capture the current state of this area through the notion of dimensions and facets.

Through this study, we arrived at answering the three research questions addressed in the introduction as follows:

RQ1 What are the main characteristics of state-of-the-art approaches on the field of collaborative product line configuration?

We followed a well-defined process to retrieve the most relevant studies in the literature. Then, we adopted a keywording process to identify the main features characterizing existing product line collaborative configuration approaches. These features have been captured within a classification framework which allows characterizing the collaborative configuration process within SPLE.

RQ2 What are the strength and weakness revealed from the comparative analysis of the existing approaches?

The outcome of this review demonstrated the potential of all approaches in performing collaborative configuration by differently ensuring the global state coherence and the consistency of the configuration at the end. However, most of current approaches do not rely on preference-based resolution process thus do not consider stakeholders satisfaction as an end-goal. Also, it was noticeable that few satisfaction measurement methods have been set up to evaluate to which extent the final product specification conforms with stakeholders requirements.

RQ3 What are the major identified challenges of collaborative configuration in the field of SPLE?

The main challenges are basically related to configuration decisions coordination among stakeholders and finding the good compromise between their configuration decisions in case of conflicts. In fact, collaboration mechanisms are extremely rigid: the resulting lack of flexibility poses several obstacles for interactive negotiation of the different requirements. The big challenge is therefore to define in-between approaches that provide enough structure to really guide the process, while offering enough flexibility at the same time to handle all the difficulties that are met in reality.

Finally, these results present a strong reason to research the product line collaborative configuration domain further, and there is a need to develop a new configuration approaches that can provide solutions to the aforementioned challenges.

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Appendix A. List of retrieved studies 2005–2018

S1. K. Czarnecki, S. Helsen, U.W. Eisenecker, Staged configuration through specialization and multi-level configuration of feature models, in: Software Process: Improvement and Practice, 2005.

S2. M. Mendonca, K. Czarnecki, T. Oliveira, D. Cowan, Towards a framework for collaborative and coordinated product configuration, in Proceeding of the 21st ACM SIGPLAN symposium on Object-oriented programming systems, languages, and applications, 2006, pp. 774–775.

S3. M. Mendona, D. Cowan, T. Oliveira, A Process-Centric Approach for Coordinating Product Configuration Decisions, in Proceedings of the 40th Hawaii International Conference on System Sciences (HICSS'07), 2007, pp. 1–10.

S4. M. Mendonca, T. Bartolomei, D. Cowan, Decision-making coordination in collaborative product configuration, in Proceedings of the 2008 ACM symposium on applied computing, 2008, pp. 108–113.

S5. M.Mendonca, D.Cowan, W.Malyk, T.Oliveira, Collaborative product configuration: formalization and efficient algorithms for dependency analysis, Journal of Software, 2008, pp. 69–82.

S6. A.Classen, A. Hubaux, P. Heymans, Analysis of Feature Configuration Workflows, in: Proceedings of the 17th IEEE International Requirements Engineering Conference, 2009.

S7. S.Chen, L. Liu, M. Tseng, Product configuration via negotiation for mass customization: An interactive goal programming approach. in: Proceedings of the 6th International Conference on Industrial Engineering and Engineering Management, 2009.

S8. M. Mendonca, D. Cowan, Decision-making coordination and efficient reasoning techniques for feature-based configuration, Science of Computer Programming, 75, (2010), pp. 311–332.

S9. E. Bagheri, T.D. Noia, A. Ragone, D. Gasevic, Configuring software product line feature models based on stakeholders' soft and hard requirements, in: Proceedings of the 14th International Software Product Line Conference. Springer, Berlin. 2010.

S10. E. Bagheri, M. Asadi, D. Gasevic, S. Soltani, Stratified analytic hierarchy process: Prioritization and selection of software features, in: Proceedings of the 14th International Conference on Software Product Lines, 2010, pp. 300–315,.

S11. A. Hubaux, P. Heymans, P.Y. Schobbens, D. Deridder, Towards Multi-view Feature-Based Configuration. in: Proceedings of the 16th International Working Conference on Requirements Engineering:Foundation for Software Quality (REFSQ'10), Springer-Verlag, Essen, Germany, 2010, pp. 106–112.

S12. R. Rabiser, P. Grunbacher, G. Holl, Improving Awareness during Product Derivation in Multi-User Multi Product Line Environments, in: Proceedings of the 1st International Workshop on Automated Configuration and Tailoring of Applications (ACoTA), 2010.

S13. Y. Bingliang, L.Renwang, and W. Xianmei. Study on product collaborative configuration design platform for mass customization', in: Proceedings of the 2nd IEEE International Conference on Information Management and Engineering (ICIME), 16–18 April, Chengdu, China, pp.489–493. 2010.

S14. E.K.Abbasi, A.Hubaux, P. Heymans, A Toolset for Feature-Based Configuration Workflows, in: Proceedings of the 15th International Software Product Line Conference, 2011.

S15. S. Soltani, M. Asadi, H. Marek, D. Gasevic, E. Bagheri, Automated Planning for Feature Model Configuration based on Stakeholder's Business Concerns, in: Proceedings of the 26th IEEE/ACM International Conference on Automated Software Engineering (ASE 2011), KS, USA, 2011, pp. 536–539.

S16. D. Dhungana, D. Seichter, G. Botterweck, R. Rabiser, P. Gruenbacher, D. Benavides, J. A. Galindo, Configuration of multi product lines by bridging heterogeneous variability modeling approaches, in: Proceedings of the 15th International Software Product Line Conference (SPLC'11), IEEE, 2011, pp. 120–129.

S17. C.M. Junior, E. Cirilo, C. Lucena, Assisted user-guidance in collaborative and dynamic software product line configuration, in: Proceedings of the IberoAmerican Conference on Software Engineering (CIbSE), 2011, pp.143–156.

S18. S. Soltani, M. Asadi, D. Gasevic, M. Hatala, E. Bagheri, Automated planning for feature model configuration based on functional and non-functional requirements, in: Proceedings of the 16th International Software Product Line Conference, 2012, pp. 56–65.

S19. G.Holl, D.Thaller, P.Grunbacher, C.Elsner, Managing emerging configuration dependencies in multi product lines. In:Proceedings of the 6th International Workshop on Variability Modelling of Software-Intensive Systems, Germany, 2012, pp. 3–10.

S20. C.Elsner, Light-weight tool support for staged product derivation, in:Proceedings of the 16th International Software Product Line Conference, 2012, pp. 146–155.

S21. G. Holl, P. Grunbacher, C. Elsner, T. Klambauer, Supporting awareness during collaborative and distributed configuration of multi product lines, in:Proceedings of the 19th Asia Pacific Software Engineering Conference (APSEC), Washington, DC, USA, 2012, pp. 137–147.

S22. G. Holl, P. Grunbacher, C. Elsner, T. Klambauer, M. Vierhauser,Constraint Checking in Distributed Product Configuration of Multi Product Lines, in: Proceedings of the 20th Asia Pacific Software Engineering Conference (APSEC). 2013.

S23. H. Zhang, R. Lin, H. Zou, F. Yang, Y. Zhao, The Collaborative Configuration of Service-Oriented Product Lines Based on Evolutionary Approach. in: Proceedings of the IEEE International Conference on Services Computing. 2013.

S24. H. Zhang, R. Lin B. Huang, X.Qi, Fuzzy multi-objective collaborative evaluation for business process family configuration. The Journal of China Universities of Posts and Telecommunications, 2013, pp. 11–16.

S25. A. Hubaux, P. Heymans, P.Y. Schobbens, D. Deridder, E. Abbasi, Supporting multiple perspectives in feature-based configuration. Software and Systems Modeling, 2013, pp.1–23.

S26. T.Klambauer, G Holl, P Grunbacher, Monitoring system-of-systems requirements in multi product lines. Requirements Engineering, Foundation for Software Quality, 2011, pp 379–385.

S27. J. Stein, I. Nunes, E. Cirilo, Preference-based feature model configuration with multiple stakeholders, in: Proceedings of the 18th International Software Product Line Conference, 2014, pp. 132–141.

S28. E. Bagheri, F. Ensan, Dynamic Decision Models for Staged Software Product Line Configuration. Requirements Engineering, 19(2), 2014, pp. 187–212.

S29. M. Noorian, E.Bagheri, W. Du, From intentions to decisions: Understanding stakeholders' objectives in Software Product Line configuration. in: Proceedings of the 26th International Conference on Software Engineering and Knowledge Engineering, Vancouver, BC, Canada, July, 2013, pp. 671–677.

S30. C. Henard, M.Papadakis, M.Harman, Y.Le Traon, Combining Multi-Objective Search and Constraint Solving for Configuring Large Software Product Lines, in: Proceedings of the 37th IEEE International Conference on Software Engineering. 2015.

S31. J. A. Galindo, D. Dhungana, R. Rabiser, D. Benavides, G. Botterweck, P. Grunbacher, Supporting Distributed Product Configuration by Integrating Heterogeneous Variability Modeling Approaches. Information and Software Technology, 2015, pp. 78–100.

S32. L.Ochoa, O.Gonzalez-Rojas, and T. Thum, Using decision rules for solving conflicts in extended feature models, in: Proceedings of the 2015 ACM SIGPLAN International Conference on Software Language Engineering, 2015, pp.149–160.

S33. L. Hotz, Y. Wang, M. Riebisch, O. Gotz, J. Lackhove, Evaluation across multiple views for variable automation systems, in: Proceedings of the 19th International Conference on Software Product Line, 2015, pp. 311–315.

S34. R.Dou, Y. Zhang, G.Nan, Customer-oriented product collaborative customization based on design iteration for tablet personal computer configuration. Computers & Industrial Engineering, 99, 2016, pp. 474–486.

S35. B. Zhang, M. Becker, Supporting product configuration in application engineering using EXConfig., in: Proceedings of the 20th International Systems and Software Product Line Conference, 2016, pp. 324–327.

S36. M.Noorian, E.Bagheri, W.Du, Quality-centric feature model configuration using goal models, in: Proceedings of the 31st Annual ACM Symposium on Applied Computing, April, 2016, pp.04–08.

S37. L.Ochoa, O.Gonzalez-Rojas, Program Synthesis for Configuring Collaborative Solutions in Feature Models, On the Move to Meaningful Internet Systems: OTM 2016 Workshops, 2016, pp. 98–108.

S38. J. Alves Pereira, Runtime Collaborative-Based Configuration of Software Product Lines, in: Proceedings of the 39th International Conference on Software Engineering Companion (ICSE-C), 2017.

S39. J.Alves Pereira, A collaborative-based recommender system for configuration of extended product lines, in: Proceedings of the 39th International Conference on Software Engineering Companion (ICSE-C), 2017.

S40. E.Lucas, T. Oliveira, K.Farias, CollabRDL: A language to coordinate collaborative reuse. Journal of Systems and Software. 131, 2017, pp. 505–527.

S41. J.Alves Pereira, P.Matuszyk, S.Krieter, M.Spiliopoulou, G.Saake, Personalized Recommender Systems for Product-line Configuration Processes. Journal of Computer Languages, Systems and Structures.2018, pp.451–471.

References

Afzal, U., Mahmood, T., Shaikh, Z., 2016. Intelligent software product line configurations. Comput. Stand. Interfaces 48 (C), 30–48. doi:10.1016/j.csi.2016.03.003.

Al-Abri, A., Jamoussi, Y., Kraiem, N., Al-Khanjari, Z., 2017. Comprehensive classification of collaboration approaches in e-learning. Telemat. Inf. 34 (6), 878–893. doi:10.1016/j.tele.2016.08.006.

Apel, S., Kolesnikov, S., Siegmund, N., Kästner, C., Garvin, B., 2013. Exploring feature interactions in the wild: The new feature-interaction challenge. In: Proceedings of the 5th International Workshop on Feature-Oriented Software Development. ACM, New York, NY, USA, pp. 1–8. doi:10.1145/2528265.2528267.

Bagheri, E., Di Noia, T., Ragone, A., Gasevic, D., 2010. Configuring software product line feature models based on stakeholders' soft and hard requirements. In: Proceedings of the 14th International Conference Software Product Lines: Going Beyond,. Springer-Verlag, Berlin, Heidelberg, pp. 16–31.

Batory, D., Benavides, D., Ruiz-Cortes, A., 2006. Automated analysis of feature models: challenges ahead. Commun. ACM 49 (12), 45–47. doi:10.1145/1183236.1183264.

Benavides, D., Trinidad, P., Ruiz-Cortés, A., 2005. Automated reasoning on feature models. In: Proceedings of the 17th International Conference Advanced Information Systems Engineering. Springer-Verlag, Berlin, Heidelberg, pp. 491–503. doi:10.1007/11431855_34.

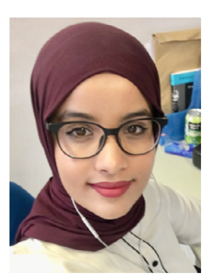
Bingliang, Y., Renwang, L., Xianmei, W., 2010. Study on product collaborative configuration design platform for mass customization. In: Proceedings of the 2nd IEEE International Conference on Information Management and Engineering, pp. 489–493. doi:10.1109/ICIME.2010.5477908.

Camarinha-Matos, L., Afsarmanesh, H., 2008. Collaborative Networks: Reference Modeling. Springer doi:10.1007/978-0-387-79426-6. New York, NY.

Chen, S., Liu, L., Tseng, M.M., 2009. Product configuration via negotiation for mass customization: An interactive goal programming approach. In: Proceedings of the 16th International Conference Industrial Engineering and Engineering Management, pp. 999–1003. doi:10.1109/ICIEEM.2009.5344221.

Clements, P., Northrop, L., 2001. Software Product Lines: Practices and Patterns. Longman Publishing.

Czarnecki, K., Helsen, S., Eisenecker, U., 2005. Staged configuration through specialization and multilevel configuration of feature models. Softw. Process Improvem. Pract. 10, 143–169.
Djebbi, O., 2011. L'ingénierie des exigences par et pour les lignes de produits. Université Paris1 Panthéon-Sorbonne Ph.D. thesis.
Djebbi, O., Salinesi, C., 2007. Red-pl, a method for deriving product requirements from a product line requirements model. In: Proceedings of the 19th international conference Advanced information systems engineering, pp. 279–293.
Dou, R., Zhang, Y., Nan, G., 2016. Customer-oriented product collaborative customization based on design iteration for tablet personal computer configuration. Comput. Ind. Eng. 99, 474–486. doi:10.1016/j.cie.2015.11.007.
Franzago, M., Ruscio, D.D., Malavolta, I., Muccini, H., 2018. Collaborative model–driven software engineering: a classification framework and a research map. IEEE Trans. Softw. Eng. 44, 1146–1175.
Gacita, R., Seplveda, S., Mazo, R., 2019. FM-CF: a framework for classifying feature model building approaches. J. Syst. Softw. 154, 1–21. doi:10.1016/j.jss.2019.04.026.
de Groote, X., 1994. The flexibility of production processes: a general framework. Manag. Sci. 40 (7), 933–945.
Holl, G., Grunbacher, P., Elsner, C., Klambauer, T., 2012. Supporting awareness during collaborative and distributed configuration of multi product lines. In: Proceedings of the 19th Asia-Pacific Conference Software Engineering. IEEE Computer Society, Washington, DC, USA, pp. 137–147. doi:10.1109/APSEC.2012.41.
Hubaux, A., Heymans, P., 2009. On the evaluation and improvement of feature-based configuration techniques in software product lines. In: Proceedings of the 31st International Conference Software Engineering. IEEE, Vancouver, BC, Canada, pp. 367–370.
Hubaux., A., Heymans, P., Schobbens, P., Deridder, D., 2010. Towards multi-view feature-based configuration. In: Proceedings of the 16th International Working Conference Requirements Engineering:Foundation for Software Quality. Springer-Verlag, Essen, Germany, pp. 106–112.
Junior, C.M., Cirilo, E., Lucena, C., 2011. Assisted user-guidance in collaborative and dynamic software product line configuration. In: Proceedings of the 14th Ibero-American Conference Software Engineering, pp. 143–156.
Kang, K., Cohen, S., Hess, J., Novak, W., Peterson, A., 1990. Feature-oriented domain analysis (FODA) feasibility study. Technical Report. Software Engineering Institute. CMU/SEI-90-TR-021.
Martinez, J., Ziadi, T., Mazo, R., Bissyandé, T.F., Klein, J., Traon, Y.L., 2014. Feature relations graphs: a visualisation paradigm for feature constraints in software product lines. In: Proceedings of the 2nd IEEE Working Conference, pp. 50–59. doi:10.1109/VISSOFT.2014.18.
Mazo, R., Dumitrescu, C., Salinesi, C., Diaz, D., 2014. Recommendation heuristics for improving product line configuration processes. In: Proceedings of the Recommendation Systems in Software Engineering. Springer Berlin Heidelberg, pp. 511–537. doi:10.1007/978-3-642-45135-5_19.
Mendonca, M., Bartolomei, T., Cowan, D., 2008. Decision-making coordination in collaborative product configuration. In: Proceedings of the ACM Symposium Applied Computing, pp. 108–113.
Mendonca, M., Cowan, D., Oliveira, T., 2007. Process-centric approach for coordinating product configuration decisions. In: Proceedings of the 40th Hawaii International Conference System Sciences, pp. 1–10.
Nurcan, S., 2004. A conceptual framework for intention driven flexible workflow modeling. In: Proceedings of the Business Process Modelling, Development, and Support, the 5th Workshop, pp. 192–199. Riga, Latvia.
Ochoa, L., Gonzlez-Rojas, O., Thm, T., 2015. Using decision rules for solving conflicts in extended feature models. In: Proceedings of the ACM SIGPLAN International Conference Software Language Engineering, pp. 149–160. doi:10.1145/2814251.2814263.
Ochoa, L., GonzÃ!'lez-Rojas, O., 2016. Program synthesis for configuring collaborative solutions in feature models. In: Proceedings of the Move to Meaningful Internet Systems, pp. 98–108.
Ochoa, L., Pereira, J.A., González-Rojas, O., Castro, H., Saake, G., 2017. A survey on scalability and performance concerns in extended product lines configuration. In: Proceedings of the 11th International Workshop Variability Modelling of Software-intensive Systems. ACM, New York, NY, USA, pp. 5–12. doi:10.1145/3023956.3023959.
Osman, A., Phon-Amnuaisuk, S., Ho, C.K., 2009. Investigating inconsistency detection as a validation operation in software product line. In: Software Engineering Research, Management and Applications. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 159–168. doi:10.1007/978-3-642-05441-9_14.
Ouali, S., Kraiem, N., BenGhezala, H., 2011. Framework for evolving software product line. Int. J. Softw. Eng. Appl. (IJSEA) 2 (2), 34–51.
Pereira, J.A., 2017. Runtime collaborative-based configuration of software product lines. In: Proceedings of the 39th International Conference, pp. 94–96.
Pereira, J.A., Martinez, J., Gurudu, H.K., Krieter, S., Saake, G., 2018. Visual guidance for product line configuration using recommendations and non-functional properties. In: Proceedings of the 33rd Annual ACM Symposium Applied Computing. ACM, New York, NY, USA, pp. 2058–2065. doi:10.1145/3167132.3167353.
Petersen, K., Feldt, R., Mujtaba, S., Mattsson, M., 2008. Systematic mapping studies in software engineering. In: Proceedings of the 12th International Conference Evaluation and Assessment in Software Engineering, pp. 68–77.
Petersen, K., Vakkalanka, S., Kuzniarz, L., 2015. Guidelines for conducting systematic mapping studies in software engineering: an update. Inf. Softw. Technol. 64, 1–18.
Pillat, R.M., Basso, F.P., Oliveira, T.C., Werner, C.M.L., 2013. Ensuring consistency of feature-based decisions with a business rule system. In: Proceedings of the 7th International Workshop Variability Modelling of Software-intensive Systems. ACM, New York, NY, USA, pp. 15:1–15:8. doi:10.1145/2430502.2430523.
Prieto-Diaz, R., Freeman, P., 1987. Classifying software for reusability. IEEE Softw. 4 (1), 6–16. doi:10.1109/MS.1987.229789.
Rabiser, R., Grunbacher, P., Dhungana, D., 2010. Requirements for product derivation support: results from a systematic literature review and an expert survey. Inf. Softw. Technol. 52 (3), 324–346.
Rabiser, R., Grnbacher, P., Holl, G., 2010. Improving awareness during product derivation in multi-user multi product line environments.. In: Proceedings of the 1st International Workshop Automated Configuration and Tailoring of Applications, pp. 1–5.
Rabiser, R., Wolfinger, R., Grünbacher, P., 2009. Three-level customization of software products using a product line approach. In: Proceedings of the 42nd IEEE Annual Hawaii International Conference System Sciences, pp. 1–10.
Rolland, C., 1998. A comprehensive view of process engineering. In: Proceedings of the 10th International Conference Advanced Information Systems Engineering. Springer Verlag Pernici, pp. 1–24.
Rolland, C., Achour, C.B., Cauvet, C., Ralyté, J., Sutcliffe, A., Maiden, N., Jarke, M., Haumer, P., Pohl, K., Dubois, E., Heymans, P., 1998. A proposal for a scenario classification framework. Requirem. Eng. 3 (1), 23–47. doi:10.1007/BF02802919.
Roschelle, J., Teasley, S., 1995. The construction of shared knowledge in collaborative problem solving. Comput. Support. Collaborat. Learn. 69–197.
Sabin, D., Weigel, R., 1998. Product configuration frameworks-a survey. IEEE Intell. Syst. 13 (4), 42–49. doi:10.1109/5254.708432.
Salinesi, C., Mazo, R., Diaz, D., Djebbi, O., 2010. Using integer constraint solving in reuse based requirements engineering. In: Proceedings of the 18th IEEE International Conference Requirements Engineering, pp. 243–251.
Schafer, J., Frankowski, D., Herlocker, J., Sen, S., 2007. Collaborative filtering recommender systems. In: The Adaptive Web: Methods and Strategies of Web Personalization. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 291–324. doi:10.1007/978-3-540-72079-9_9.
Soares, L.R., Schobbens, P.-Y., .do Carmo Machado, I., de Almeida, E.S., 2018. Feature interaction in software product line engineering: a systematic mapping study. Inf. Softw. Technol. 98, 44–58. doi:10.1016/j.infsof.2018.01.016.
Soltani, S., Asadi, M., Gašević, D., Hatala, M., Bagheri, E., 2012. Automated planning for feature model configuration based on functional and non-functional requirements. In: Proceedings of the 16th International Conference Software Product Line. ACM, New York, NY, USA, pp. 56–65. doi:10.1145/2362536.2362548.
Stein, J., Nunes, I., Cirilo, E., 2014. Preference-based feature model configuration with multiple stakeholders. In: Proceedings of the 18th International Conference Software Product Line,, pp. 132–141.
Triki, R., Mazo, R., Salinesi, C., 2014. Combining configuration and recommendation to enable an interactive guidance of product line configuration. In: Proceedings of the Recommender Systems, pp. 135–155.
Wieringa, R., Maiden, N., Mead, N., Rolland, C., 2006. Requirements engineering paper classification and evaluation criteria: a proposal and a discussion. Requirem. Eng. 11 (1), 102–107. doi:10.1007/s00766-005-0021-6.
Xiong, Y., Hubaux, A., She, S., Czarnecki, K., 2012. Generating range fixes for software configuration. In: Proceedings of the 34th International Conference Software Engineering. IEEE Computer Society, Zurich, Switzerland, pp. 58–68.
Zhang, H., Babar, M., 2009. Adopting Systematic Reviews in Software Engineering: An Evidence-based Report. Technical Report. Lero Software Engineering Research Centre.



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