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Software product line scoping and requirements engineering in a small and medium-sized enterprise: An industrial case study

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ABSTRACT

Software product line (SPL) engineering has been applied in several domains, especially in large-scale software development. Given the benefits experienced and reported, SPL engineering has increasingly garnered interest from small to medium-sized companies. It is possible to find a wide range of studies reporting on the challenges of running a SPL project in large companies. However, very little reports exist that consider the situation for small to medium-sized enterprises and these studies try develop universal truths for SPL without lessons learned from empirical evidence need to be contextualized. This study is a step towards bridging this gap in contextual evidence by characterizing the weaknesses discovered in the scoping (SC) and requirements (RE) disciplines of SPL. Moreover, in this study we conducted a case study in a small to medium sized enterprises (SMEs) to justify the use of agile methods when introducing the SPL SC and RE disciplines through the characterization of their bottlenecks. The results of the characterization indicated that ineffective *communication and collaboration*, long *iteration* cycles, and the absence of *adaptability and flexibility* can increase the *effort* and reduce *motivation* during project development. These issues can be mitigated by agile methods.

1. Introduction

Software product line (SPL) has been applied in a wide variety of domains, such as driver firmware (Iwasaki et al., 2010), security inspection (Li, 2010), enterprise resource planning (Hamza et al., 2010), and operational research (Demir et al., 2010), as a means to achieve quality improvements, and reductions in time to market (Pohl et al., 2005; Clements and McGregor, 2012). Despite the aforementioned benefits, during SPL adoption several issues must be overcome by the company such as the required up-front investment to achieve an operational SPL, challenging adoption barriers, and the lack of guiding empirical studies in the field (Bastos et al., 2011).

The scoping (SC) and requirements (RE) disciplines are extremely important to a SPL, as they define the initial activities and steps of the SPL life-cycle. For this study, we consider SC as a planning activity that defines the boundaries of the SPL by deciding which features are "in" (economically relevant to be included as SPL core assets) and "out" (not economically relevant). We consider RE as the statements that describe the features such as the behavior descriptions, properties, qualities, and the constraints that the feature should satisfy. To specify these statements, we used textual specifications for features, requirements, and use cases. Thus, a feature can represent a requirement, a selection amongst optional or alternative requirements, nonfunctional requirements, and implementation characteristics. A set of features describes a domain.

There are few industrial studies in the literature that characterize the SPL SC and RE disciplines. Moreover, studies that justify the use of agile methods to improve the SPL SC and RE disciplines are scarcer. All these studies try develop universal truths for SPL but the lessons learned from empirical evidence need to be contextualized (Dyba, 2013).

The goal of this study is to justify the use of agile methods when introducing the SPL SC and RE disciplines in a SME through the

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characterization of their bottlenecks with contextualized empirical evidence (Dyba, 2013). We grouped characterized bottlenecks and identified the weaknesses in a number of aspects that the literature mentions as success factors for agile software development (Silva et al., 2011). The success factors are: the *effort* (Dybå, 2000; Hazzan and Hadar, 2008; John and Eisenbarth, 2009), *communication and collaboration* (Dybå, 2000; Hazzan and Hadar, 2008; Pettersson et al., 2008; Stelzer and Mellis, 1999; Niazi et al., 2005), *iteration and adaptation* (Hazzan and Hadar, 2008; Pettersson et al., 2008), *motivation* (John and Eisenbarth, 2009), and requirements and technology *volatility*.

These factors were chosen, mainly, because of a systematic mapping study into SPL and agile methods (Silva et al., 2011). In this mapping study, the primary studies partially addressed each one of these factors.

As these factors can have different meanings, for this study we defined them as:

- **Effort factor**. The time spent by one participant on development tasks such as *specify features* and *validate requirements*.
- **Communication and collaboration factor**. The interactions among the team members and how these interactions contribute to the development of the tasks.
- **Motivation factor**. The participant's feelings regarding the tasks associated with a discipline before, during, and after performing them.
- **Iterativeness factor**. The potential of the disciplines to foster the building scope and requirements artifacts through several iterations in sequence. In that each iteration is a self-contained mini-scoping or mini-requirements discipline composed of tasks such as *identify features*, *specify requirements*, and *inspect use cases*.
- **Adaptability factor**. The potential of the disciplines to foster adjustments in the artifacts, team, technology, and process to become more effective.
- **Volatility factor**. The changes from the customer needs, technology, and domain, which must be considered in the adopted process.

This paper discusses the challenges that emerged from the weaknesses and the lessons learned. The challenges are discussed from the point of view of mitigation strategies and the use of agile approaches to overcome identified bottlenecks.

The remainder of this paper is structured as follows: Section 2 describes related work. Section 3 describes the context in which we performed the case study. Section 4 discusses the study design, by stating the research questions, and the data collection, analysis and validity procedures. The results are presented in Section 5. Section 6 presents the threats to validity. Section 7 describes the main findings, the lessons learned, and identified challenges, and finally, Section 8 describes the conclusions, implications, and future work.

2. Related work

Some studies have provided data about *effort*, use of *communication, iterativeness, adaptation, motivation*, or *volatility* regarding SPL SC or RE. The following studies are briefly described, since they provide empirical data regarding SPL SC or RE.

In the study by Knauber et al. (2000), the authors describe initial results and lessons the application of the PuLSE approach (Bayer et al., 1999) in six SMEs. Despite the limited resources in the companies, the scoping discipline contributed to the creation of a business vision and the identification of new business opportunities. However, the study provided few details regarding the *effort, communication and collaboration, iterativeness, adaptability, motivation*, and *volatility*.

In Gacek et al. (2001) and Verlage and Kiesgen (2005), the authors describe lessons learnt and drawbacks regarding the introduction of a SPL (using the PuLSE approach (Bayer et al., 1999)) in the company *Software AG*. The company transitioned from legacy systems to save development effort and get started on a stable platform of domain functionalities. The scoping team (from development, management, sales, and marketing units) was not a permanent team and the meetings occurred only when major scoping activities were required. Communication was considered effective and fast. The initial findings of these two studies also contributed to increase the body of evidence in the SPL area. However, they did not address weaknesses in iterativeness and motivation.

Complementing the discussion in Bayer et al. (1999), the work of Schmid (Schmid, 2002) presents a well-documented approach for SC and its extensive validation in *Software AG* and *Bosch* companies. The approach describes the product line, its domains and features and performs an assessment of the reuse benefits and risks, while identifying assets for the product line. The extensive validation was accomplished in the case studies. The results have contributed to SPL scoping. However, the study focused only on the *effort* factor.

Herrmann and Liebehenschel discuss their experiences in a study (Herrmann and Liebehenschel, 2011) focusing on *effort, communication, feedback, adaptability*, and *volatility* when performing requirements engineering for SPL. The study applied SPL RE in several automotive systems. Although they present various aspects of SPL RE that helped them to generate the SPL requirements documents, detailed information about what they consider scoping as well as information on weaknesses in *effort, communication, iterativeness, adaptability, motivation*, and *volatility* are missing. Yu, Geng, and Wu discuss a case study (Yu et al., 2012) that evaluated an approach to provide traceability between requirements and features for individual applications within same domain. After the approach defines a feature tree and establishes traceability with requirements for each application, the approach then merges all the models to form a domain feature tree model as well as traceability between the domain features and requirements. Although the study has relevant aspects, such as the traceability between features and requirements, the paper does not describe the factors addressed in our work.

Noor describes two studies (Noor et al., 2006, 2008), where the collaboration factor is alleviated through the collaboration engineering technique. This improves *communication and collaboration* between SPL stakeholders during the SPL SC. The authors organized the approach in three different layers: *(i)* **process layer**, which defines the objectives, tasks and participants of the process, *(ii)* **pattern layer**, where the process is modeled using patterns from collaboration engineering, and *(iii)* **thinKLets layer**, where the tasks are decomposed to allow their execution using thinKLets.

The approach facilitates stakeholder involvement and the results are based on an industrial context with the reengineering of legacy systems into a SPL. However, results about the *effort, motivation*, and *volatility* variables were not reported in the studies. The aforementioned studies partially address our objective. As stated previously in this section, the studies focused on one discipline, for example scoping, or on a few variables, for example, *effort* and *collaboration*. They did not aim to investigate, qualitatively, the weaknesses of several variables for scoping and requirements disciplines as well as their effects on each other. This paper investigates the *effort, communication and collaboration, iterativeness, adaptability*, and *volatility* during the SPL SC and RE disciplines through a qualitative study. As a result, this study aims to justify the use of agile methods when introducing the SPL SC and RE disciplines. Additional information about these studies and others that addressed SPL SC or RE, although with limited data about our