Pak. J. Engg. Appl. Sci. Vol. 24 January, 2019 (*p.* 57–65)

Requirement-Based Feature Modeling in Software Product Line

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Abstract

Software Product Line is broadly used for reusability of resources in a family of products. Feature model is commonly used tool to model the variation within a software product line in a specific domain. But the selection of the suitable features for a specific application depends on its stakeholder's intentions. It can be challenging and time-consuming without a proper understanding of the requirements of the customer. Thus, it is necessary to analyze the domain and requirements of the organization to build a suitable product line. This paper proposes extended feature modeling framework in which feature model is built on the basis of domain goal model that identifies stakeholder's goal, overcomes variability issues and satisfies the customer. It has four layers i.e. Goal analysis layer, Domain goal model layer, feature analysis layer and feature model layer. Finally, this framework is evaluated by the case study of pharmacy management system.

Key Words: SPL, Software product line, Feature model, Domain goal model, Extended feature modeling framework

1. Introduction

The software product line plays an important role in producing cost-effective and improved quality software products [18]. Software product line engineering encompasses two fields i.e. domain and application engineering. Domain engineering deals with analyzation of domain-specific requirements to design a common product line architecture and SPL component library. Application engineering is concerned with the generation of individual products from the SPL component library [6]. Feature modeling is proved to be an effective method for domain modeling and analysis [19]. Commonality measures the reuse ratio of features among the products in an SPL but it is difficult to analyze variability at large scale [7]. Feature modeling was proposed to the domain analysis phase of domain engineering to identify similar and variable requirements [6]. Feature modeling helps in identification of system requirements and features in SPL. It helps in product configuration and reusable asset development in software product line [20]. But the criteria on which should the features of a software product line be nominated for a target software application, which is to be extracted from the software product family. Therefore, the selection of the appropriate features for a specific domain depends on the understanding of its stakeholders' intents. It also depends on the relationship between stakeholder's intentions and the available software product line features [3]. This paper proposes a framework that identifies the customer requirements and then the basis of those requirements formulates a feature model. Goal identification is important because it ensures that selected features address all concerns, objectives and stakeholder's requirements eliminating irrelevant features. The rationale after the process to select of a feature is obvious for the stakeholders.

2. Related Work

Software product line has become an evolving area of research interest. Different methods have been described to identify product line engineering problems. These methods have diverging processing and application domains and it is problematic to identify their commonalities and variation. In [17], Iris and Mark presented an automated method i.e. CoreReq to design core requirements using existing product requirements to analyze software product line but it did not considered non-functional requirements to formulate software product line. In [5], E. Janssens et al. proposed an approach named as twofold, which is based on feature modeling. The approach has been established for two different domains, the games for children and e-shop web applications domain. The approach has been evaluated by two explorative case studies but it did not considered stakeholders' requirements. In [1], Ali and Hong proposed requirements-driven technique, that facilitate the requirements engineering process by analyzing requirements, using social network sites but it did not analyze domain and features, required to develop product line. In [8], Antonia et

al. defined systemic approach to formulating feature model for SPL development. They created a single goal graph from multiple graphs of same SPL family and consider the leaf goals, as the participants of features. They considered the common goal as the mandatory feature and the specific goal as the optional feature. But the resulting feature model might be incomplete since they emphasized only on leaf goals. In [2] M. H. Geith et al. introduced a technique for extending a feature model for ERP systems. It translates the requirements of the extended feature model into the form-based model which is a conceptual model to provide simplicity for the stakeholders, to increase the participation of different parties of stakeholders but non-functional features were not considered in it. In [3], Asadi et al. proposed a goal-oriented RE framework that clearly bridges features of the software product line to stakeholder's goals and objectives. It has limitations of non-functional qualities and variability in SPL. In [21], H. Yadav et al. proposed the feature analysis, using a feature model in an e-mail SPL. They analyzed the core features in a SPL using two fundamental attributes i.e. reusability and consistency. This improves the understanding of reusable and consistent core features and thus assists in deriving new SPL but it did not considered requirements of stakeholders. In [20], Tan and Lin proposed Aspect-oriented framework for modularization of crosscutting relations among features. Aspect-oriented techniques model the quality-based variations in feature model but it lacks reusability and change management. It can be difficult and time-consuming without a proper understanding of the objectives of feature modeling. In [23], Yu, Chen, and Zhang presented the goal-oriented I* framework to construct a domain feature model but it might be subjective and inaccurate because it manually assigned the cardinalities to only tasks, goals, and resources except for soft goals. Larissa et al. [12] proposed a systematic mapping study to analyze the state of-the-art of feature interactions in software product line but they did not analyze requirements of stakeholders and domain. Our framework differs from other approaches in terms of the domain. It addresses the SPL domain that shows a higher level of variations and complexities. We propose a framework, by extending feature model on the basis of domain goal model, which overcomes the issue of variability, reusability and helps in identification of goals of product line development.

3. Methodology

A Feature model is a prevailing tool used to model requirements in any domain on a high abstract level. We propose extended feature modeling framework on the basis of domain goal model that identifies stakeholder's goal and overcome variability issues. This framework has four phases i.e. goal analysis, domain goal model, feature analysis and feature model. On the demand of a new product, reasoning, on the basis of stakeholders' intentions is accomplished on the domain goal model to formulate feature model. In this framework, a domain goal model is derived from the domain and requirement analysis and feature model is created by relating the domain goal model and feature analysis. The four phases of the framework are:

A. Goal analysis

a) Domain analysis: In this phase, domain knowledge is obtained and the main ideas of the domain are confirmed by collaborating with an organization.

b) Requirement analysis: Domain and Requirements analysis are a mutual process. In this phase, the functional, non-functional and system requirements are defined by prevailing products information in the domain.

B. Domain goal model

In this phase, we have built a domain goal model by the analysis of the domain and requirements. It captures stakeholder's requirements by analyzing high-level functional goals, soft goals or non-functional and system goals. Functional goals are required actions for the software product line realization. Soft goals are quality features of the SPL. System goals are requirements of the system. Plans are used to operationalize stakeholders' requirements and goals. Both functional and soft goals can be improved into sub-goals by specialization and decomposition.

C. Feature analysis

In this phase, we extract the relevant features according to domain requirements and analyze every feature and should be individually named i.e. functional, non-functional and system

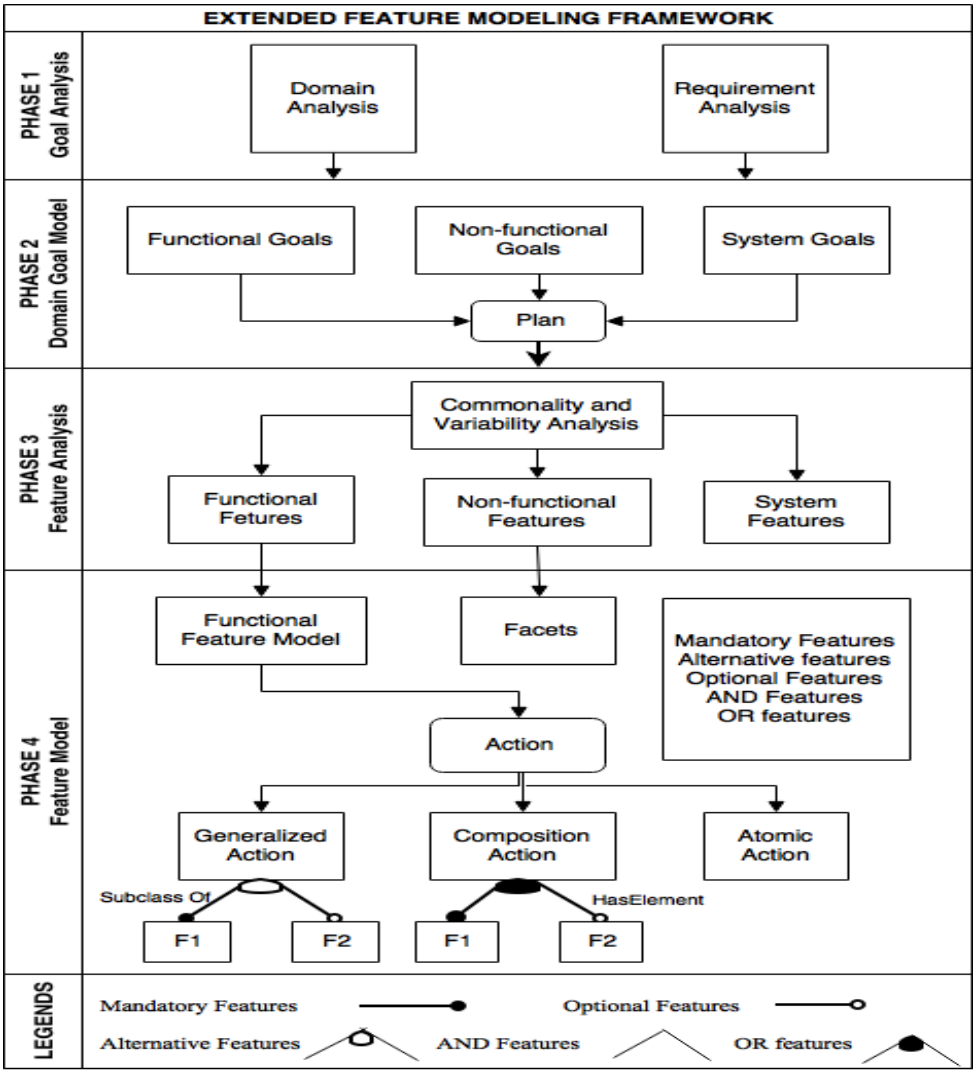

Fig. 1: Extended Feature Modeling Framework

features. The system provides the functional feature and user can easily see it. The non-functional feature elaborates the estimated presentation of the application system or other properties. We also make the similarity & variability analysis according to the relationship between the features.

D. Building a feature model

In this phase, feature model is built on the basis of features, relationships between them and the variability of features. According to domain goal model and feature analysis, we built functional, non-functional, and system feature model. Functional features model comprises of hierarchal and dependency relation of functional features. While non-functional features model contains hierarchy and dependency relationships of non-functional features. Feature models are signified both graphically and formally [3]. Graphical representation of the model in the form of feature diagram helps in managing the variabilities at larger granularity. The feature diagram contains commonalities and variations of features, the inter-feature relationship. In this model, features and their dependency relationships are subdivided into numerous categories:

a) Mandatory features reveal the product's commonality and these features are mandatory.

b) Optional features that show different characteristics and their inclusion in parent description are not mandatory.

c) Alternative feature group in which one feature is incorporated in parent description from feature group. It also reflects the variability of products.

d) Or feature group in which parent description feature can include one or more features from a feature group.

e) An action denotes a business activity of various granularities containing semantics specific to domain.

f) HasElement is a specialism relationship and specializes in the role of a parent feature into that of sub-features.

g) Composition Action is a type of action that can be divided into sub-actions with HasElement relations.

h) subClassOf is the self-defined function of two actions to represent direct speciality relationship among them.

i) Generalization Action is an action in which sub-actions are dedicated from it with the subClassOf relation.

j) Atomic Action represents the leaf of a feature model that cannot be decomposed further.

k) Facets are viewpoints or perspectives of specific accounts for certain operations.

4. Case Study

A case study was performed in a Pharmaceutical company that wants to make a pharmacy management system for their retail pharmacy setup. The phases of the study are case study design, including objective, conceptual framework, and sampling strategy, data collection, and analysis of data.

A. Company background

Linta Pharmaceuticals Pvt. Ltd. is a medicine company, located in Rawat industrial zone, which provides high-quality medicines. They have started their journey in 2012 with a small structure, now they have 50 - 100 employees. They formulate the medications and provide these medicines to the healthcare facilities. Now they want to extend their business by creating their own pharmacy setup. Their main area of interest is to develop a pharmaceutical management system to facilitate pharmacy retail setup.

B. Case study design

Three components were considered to design a case study i.e. the objective of the study, Conceptual framework and Sampling strategy.

a) Objective: The purpose of this study is to assess the benefit of applying the extended feature modeling framework.

b) Conceptual framework: The conceptual framework which relates the activities to be studied is the extended feature modeling framework, where the product line requirements are indicated on the basis of features.

c) Sampling strategy: The sampling strategy is centered on an embedded multiple-case study design. The extended feature modeling framework is applied to analyze SPL for a specific case. The selected case is Pharmacy management system and units of analysis are the Pharmacy domain and stakeholder's requirements.

C. Data collection

Data was collected by surveying company employees and software engineers who are involved in this project. They were asked multiple questions to gather information on the basis of which we have designed an extended feature modeling framework, for pharmacy management system, described in fig. 2:

a) Which domain is being studied?

A pharmaceutical domain is being studied in this case. The pharmaceutical management system can be improved by using an extended feature modeling framework, as it provides a complete layout of the system, to manage pharmacy in the quick and easy way.

b) What are the requirements of an organization?

This step analyses requirements of a company pharmacy management system. Functional requirements of the organization are to develop a system for the rational sale of medications, under the supervision of qualified personnel. Non-functional requirements are to have safe storage of medications.

c) How are the goals specified?

Goals are specified on the basis of domain and requirements of the organization. The functional goal is to have the pharmacy management system decomposing into inventory management, rational sale and area management goals. While soft goal i.e. system safety is decomposed into storage safety and record operation.

d) Which features are specified to design feature model for pharmacy management system SPL?

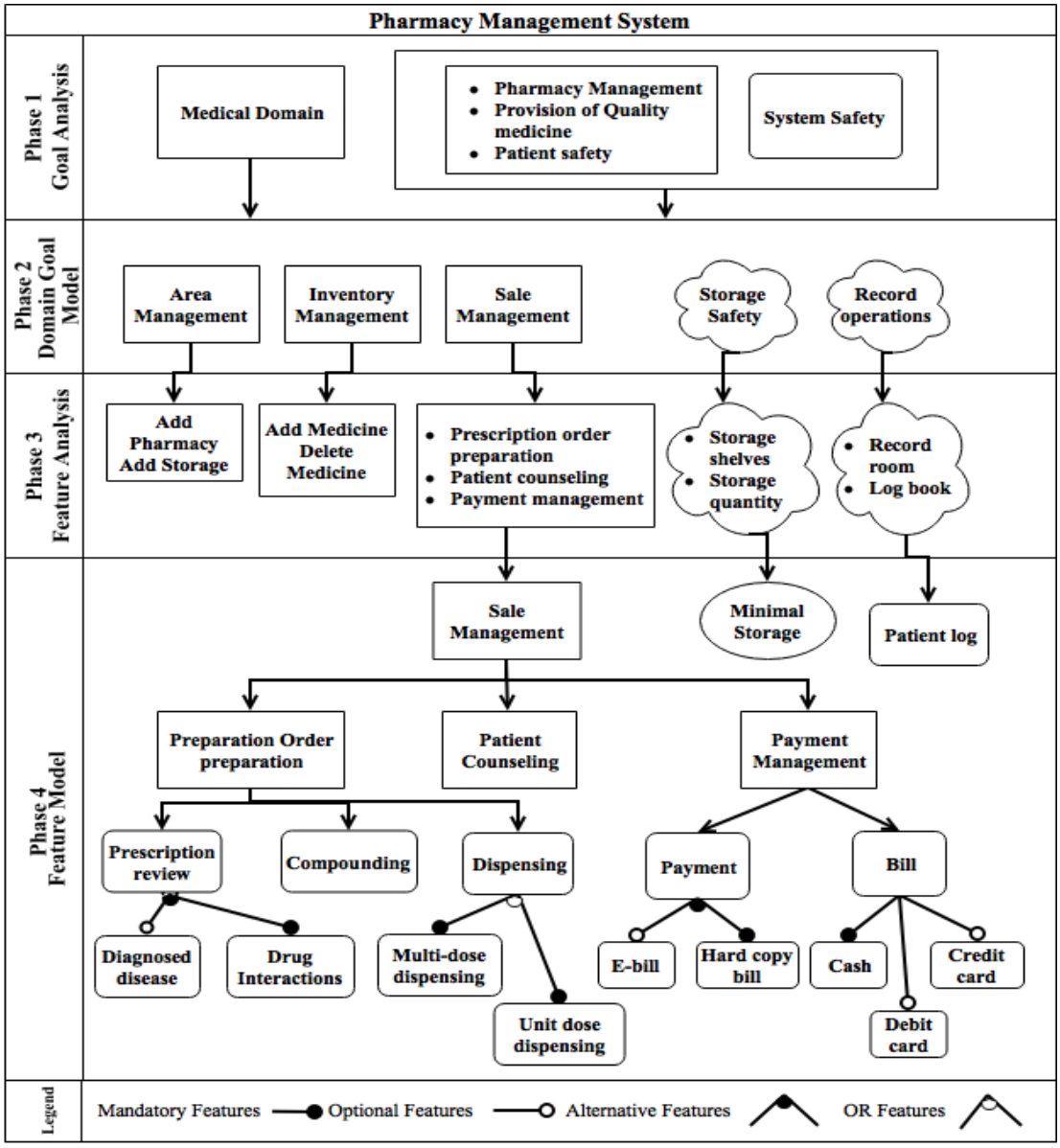

Fig. 2: Extended feature modeling framework for Pharmacy management system

Features are specified to functional goals i.e. inventory management has features to add medicines or delete medicines, area management has features to add pharmacy or add storage and sale management has features of taking and proceeding the order. Non-functional goals i.e. storage safety has features of Storage shelves and the number of drugs to be stored. System goals include record operation that has features of record area and record book. The feature model is developed after analyzing the goals and features. After the development of the feature model, the high-level goals can be specified for each product and the satisfaction level can also be stated for each soft-goal. The functional goals are aided by actions e.g. sale management is aided by prescription order preparation and pay management. Prescription order preparation is composition action and decomposed into Prescription review, compounding, dispensing to patient and order verification by HasElement relationship. Payment management is generalization action and decomposed into bill and payment by subClassOf relationship. Patient counseling is an atomic action, which cannot be decomposed further. As for the soft goals, Patient Log is dynamic action specialized from record operation and storage safety is a static action decomposed to minimal storage, i.e. facet related to medication quantity.

D. Data analysis

We have analyzed the case study by conducting the survey from company employees

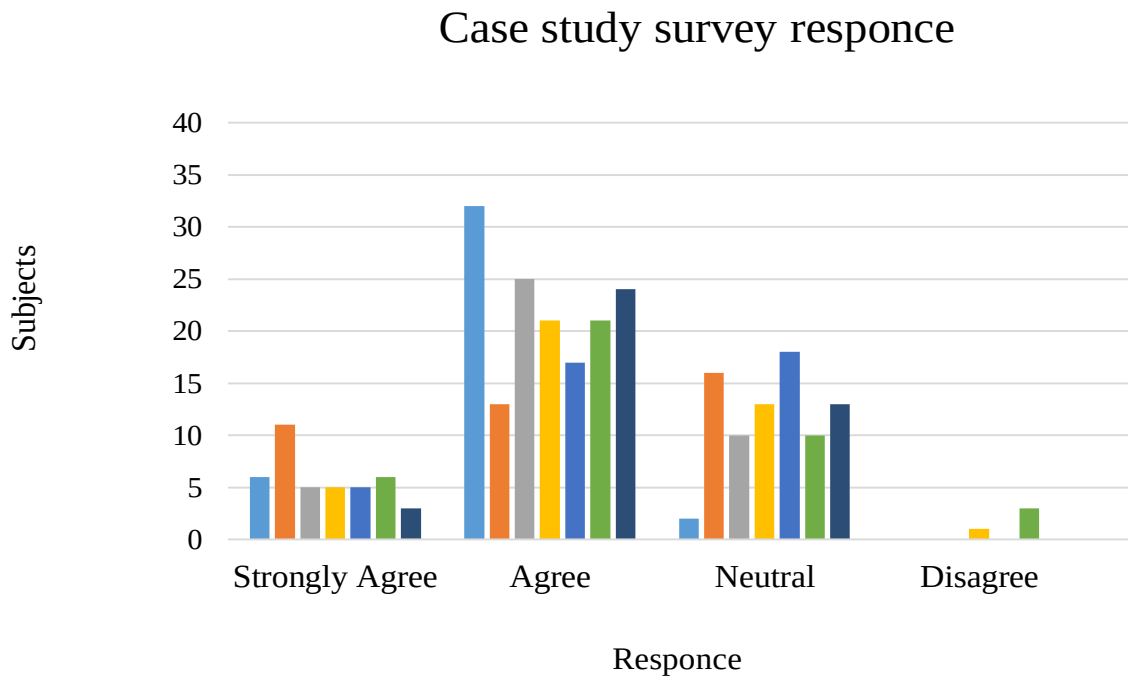

Fig. 3: Graphical representation of the response to case study survey

and software engineers who were involved in this project. The survey comprises of questions adapting two constructs of the Technology Acceptance Model which are Perceived Usefulness and Perceived Ease of Use. The items in the survey were expressed by a 5-point Likert scale. Randomization of several items in a single construct was done to avoid biasness in response. PEOU was considered by using three items and PU was considered by using four items in the survey. We have defined the following null hypotheses on the basis of our survey:

$H1_0$: Extended feature modeling framework is perceived as not easy to use.

$H2_0$: Extended feature modeling framework is perceived as not useful.

Then we have checked the reliability of the case study survey by using Cronbach's alpha in SPSS statistical tool. The results of the Cronbach's alpha reliability analysis are PEOU = 0.861; PU = 0.985, which shows the items in the survey are reliable. In table 2, we have analyzed the response of case study survey, by using SPSS Statistical tool. We have also used 1-tailed one sample t-test to check hypothesis. The questionnaire for a survey regarding the usefulness and ease to use this framework is designed in table 1, as follows:

Table 1: Questionnaire to evaluate a case study

Questionnaire	
PEOU1	It is simple and easy to gather pharmaceutical requirements using our Framework.
PEOU2	It is easy to use requirement specifications to manage sales, area and inventory.
PEOU3	It is easy for me to design pharmaceutical setup using this framework.
PU1	I believe that this framework would save the time required to develop pharmaceutical management system.
PU2	I believe that this model would upgrade my performance in managing prescription orders.
PU3	This model specifies the storage management criteria for medicines.
PU4	I believe that the payment specifications obtained from the framework are structured, clear, brief and obvious.

Table 2 illustrates response results and overall descriptive statistics for the perceived variables. This result is also illustrated in fig. 3, which shows that maximum responses to all seven questions lie under an agreed category.

Table 2: Statistical results of case study survey

	Mean	**SD**	**Cronbach's Alpha**	**t**	**P-value**
PEOU	2.091	0.599	0.861	1.638	0.08
PU	2.272	0.668	0.965	1.733	0.079

Table 3: Comparison with existing approaches

Features	**Proposed framework**	**FW1 (Iris & Mark (2019)**	**FW2 (M. H. Geith et al. (2016)**	**FW3 (H. Yadav et al. (2018)**	**FW4 (Ali & Hong (2018)**
Stakeholder requirements	Yes	Yes	Yes	No	Yes
Soft goals identification	Yes	No	No	Yes	No
Domain analysis	Yes	No	No	No	No
Feature analysis	Yes	No	Yes	Yes	No
Variability analysis	Yes	No	No	Yes	Yes
Reduce failure rate	Yes	No	No	No	No
Improve product quality	Yes	Yes	Yes	No	No

The results shown in Table 2 indicate that the items in the case study survey are reliable. Hence we reject the null hypothesis concluding that our framework is perceived as easy to use and useful. Thus after analyzing the results of a survey, it is concluded that the subjects perceived extended feature modeling framework as useful and easy to use.

5. Comparative Analysis

In this section, our proposed framework is analyzed by comparing it with existing frameworks. Some identified parameters are used to compare. It is analyzed that many existing frameworks described in literature help in resolving many issues but they have some ambiguous features that are not considered. Our proposed framework has these features to overcome deficiencies in previous frameworks, thus improving product quality, goal analysis, reusability, customer satisfaction and reducing failure rate . This comparison is described in Table 3.

6. Conclusion and future work

Software product line is an emerging platform to develop software products from reusable artifacts. There are many issues of variability management arising in the product line. For this purpose, feature modeling is widely used to capture similarities and variabilities in domain analysis of product line. But it is desired to select the suitable features depending on intentions of the customer. It is difficult and time-consuming to model specific application without a proper understanding of goals. Hence to overcome this ambiguity, we propose a framework by extending feature model on the basis of domain goal model. This framework has four phases i.e. goal analysis, domain goal model, feature analysis and feature model. This approach identifies the variability within products and reuses core assets to develop new software products. It helps in customer satisfaction by designing application after understanding proper intentions of stakeholder.

The feasibility of extended feature modeling framework was evaluated using a pharmacy management system case study. The results of case study show that the subjects perceived our framework as useful and easy for stating the functional or non-functional requirements, to specific software product line. However, the framework requires further empirical analysis with complex and larger software product lines. In future, we are planning to apply our framework in the generation of other product lines at the domain engineering field.

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