Value-Based Requirements Analysis for Product families: A Goal and Scenario Oriented Approach

Minseong Kim       Sooyong Park
Department of Computer Science and Engineering
Sogang University
Sinsu-Dong, Mapo-Gu, Seoul, 121-742, REP. of KOREA
{minskim, sypark}@sogang.ac.kr

ABSTRACT
For successful software product lines, it is required to able to answer the questions: “What will the investment in product lines give to our business and stakeholders as well as customers?” and “How to maximize the business value and stakeholder value in product lines?” The decisions you make on product line development need to be much coupled with value propositions that establish product line development. Traceability to the value propositions becomes more important and relevant than traceability to requirements. The value can be realized and delivered to stakeholders by achieving goals of organizations in product line development. Consequently, the purpose of the paper is to introduce value-based requirements analysis through goals and scenarios in order to elicit requirements and analyze C&V for delivering value to stakeholders in product lines. To achieve this, we suggest value-based goal and scenario model for product families and requirements analysis process that is value creation process by goals and scenarios.

KEYWORDS
Software product lines, Value-Based Software Engineering, Requirements Analysis, Commonality and Variability

INTRODUCTION
Software product line approach has attracted a lot of attention from both researchers and practitioners [1,2,3]. The idea behind product line concept is for organizations to develop a product family from reusable core assets rather than from scratch. To apply product line approach, one must understand how product line approach addresses the company’s strategic business goals and be able to determine the expected return on adopting a product line process [6]. More significantly, for successful software product lines, it is required to able to answer the questions: “What will the investment in product lines give to our business and stakeholders as well as customers?” and “How to maximize the business value and stakeholder value in product lines?” The decisions you make on product line development need to be much coupled with value propositions that establish the product line development.

RELATED WORK
Value-based software engineering
Even though neglecting the value added by software is increasingly risky in today’s world of software-driven product lines changes in the information technology
marketplace, much of current software engineering practice and research is done in a value-neutral setting. Also, value-neutral approaches are unable to deal with most of the sources of software project failure [9]. Thus, the primary thesis of value-based software engineering (VBSE) [9] is that the integration of value considerations into the system’s definition, design, development, deployment, and evolution is critical to the system’s success. After all, the fundamental goal of all good design and engineering is to create maximal value added for any given investment.

Goal-driven and scenario-based requirements analysis

In Requirements Engineering (RE), goal modeling is an effective way to identify requirements [15]. Goals provide the rationale for requirements. A goal refinement tree provides traceability links from high-level strategic objectives to low-level technical requirements [16]. Goal elaboration provides a value oriented approach to identifying critical off-nominal or missing requirements. And, by capturing examples and illustrations, scenarios help people in reasoning about complex systems [10]. Lately, some proposals have been made to couple goals and scenarios together in order to overcome some of the deficiencies and limitation of goal-driven and scenario-based approaches used in isolation [10,11,12]. Yet, the approaches are just for single systems, not for a family of related systems. Consequently, it can be seen that these are not concerned with a product family, that is, common and variant requirements of products.

Domain Analysis for Product Families

Recently, feature-oriented approaches [4,5,14] have been used extensively to analysis C&V among products in industry and academia since the FODA method [14] was introduced in 1990 by the Software Engineering Institute [2,3,4]. However, the approaches contain no formal mechanism to systematically identify features and C&V, and provide the rationale for them, particularly in immature domains or an envisioned market [7,8,13,20]. Further, the approaches do not directly show how the results of C&V analysis will satisfy an organization’s high-level business goals and provide the rationale for C&V [13] and thus, do not consider the value delivered to stakeholder.

VALUE-BASED GOAL AND SCENARIO MODEL FOR PRODUCT FAMILIES

In our approach, the requirements for products of a product family, namely product line requirements (PLR for short) are composed of goals and scenarios with respect to the value added by a product line. The PLR and their inter-relationships constitute the goal and scenario model which is extended for product families. PLR can be assembled together through refinement (‘Refined by’), mandatory (‘AND’), alternative (‘Alternative-OR’) and optional (‘Optional-OR’) relationships. The mandatory, alternative and optional relationships establish a horizontal link between product line requirements and the refinement relationship establishes a vertical link between them. Figure 1 gives an overview of the model.

Figure 1. The goal and scenario model

This model is based on the domain requirements model defined for product lines in [13]. Thus, the mandatory relationships are related to what are common to products, i.e., commonality, and the alternative and optional relationships are related to what differentiate them, i.e., variability.

The concept of value, goal and scenario

The term value is used to denote a product’s perceived overall benefit relative to its cost [6]. A motivating factor for all projects and systems is the desire to create or add more value for any given investments. Thus the value is the reason for which software projects are established [9]. Business considerations determine the value that must be created in systems being developed, and the value is not just cost and above cost. In the paper, we define value attributes
that is value drivers for creating and adding value for stakeholders. The value attributes can be divided into system value attributes and business value attributes. First, the system value attributes are related to product itself such as product capabilities and product quality, and software/IT system development that are needed in order for the organization to realize the potential system benefits. Second, the business value attributes are non-software initiatives as Boehm’s terms [9] and needed to realize the potential benefits enabled by the software or product development, like a financial return on investment, cost of production, benefit, reputation, profits or market share, etc.

Based on the definition of a goal and scenario in [10,11,12,13], we define a goal in a product family context as an objective of the business, organization or system that some stakeholder hopes to achieve in a product family, and a scenario as a possible behavior limited to a set of purposeful interactions in order to achieve some goal in a product family. A scenario is composed of one or more actions being user or system interactions with products in a product family. Scenarios have their goals and the goals are also achieved by the scenarios. Therefore, the value can be elicited from stakeholders with respect to products, and realized by achieving goals of organizations that is, satisfying the goals that stakeholders hope to achieve in product lines (see Figure 2). In addition, the goal refinement or elaboration in goal hierarchy tree is conducted to create the value, and scenarios are authored for goal to maximize the value. Thus, the value can provide the criteria for goal achievement and discovery.

The aforementioned four types of relationships between PLR lead to an organization of the collection of requirements as a hierarchy of PLR in the goal and scenario model, as illustrated in Figure 1.

- **Mandatory relationship:** The mandatory relationship leads to a horizontal AND structure between PLR in the model. AND relationships among PLR (‘AND’ association in Figure 1) link the PLR that are required together to achieve more high-level requirements. The relationships are identified based on C&V analysis within products of a product family.
- **Alternative and optional relationship:** Alternative relationships (‘Alternative-OR’ association in Figure 1) represent alternative ways of fulfilling the same goal in a product family. Optional relationships (‘Optional-OR’ association in Figure 1) represent options of fulfilling the same goal.
- **Refinement relationship:** Based on the results of C&V analysis, refinement is used to identify and describe PLR at different levels of abstraction (‘Refined by’ association in Figure 1). Refinement is directed by the scenario part of our model. Every action in a scenario Sc at level i is looked upon as a goal to be achieved at level i+1.

### VALUE-BASED REQUIREMENTS ANALYSIS FOR PRODUCT FAMILIES BY GOALS AND SCENARIOS

In product lines, the value delivered to stakeholders is elicited and reconciled into a satisfactory set of objectives for the product lines by the value-based process shown in Figure 3. In the paper, we want to focus on the goal and scenario oriented analysis for analyzing PLR and C&V based on the value.

**Figure 2. The relationships among value, goal and scenario**

**Figure 3. The value-based process**

We organize the requirements collection in a four levels
abstraction hierarchy, i.e. business, service, interaction and internal level for clarifying the concerns of requirements, and help separating concerns in requirements elicitation in product families in terms of value creation.

- Business level: The aim of the business level is to identify and describe the highest level goals or strategic objectives and final purpose in order to create and deliver value to stakeholders.

- Service level: This level addresses identifying products that will be members in a product family to achieve the business goals by considering business concerns such as the business strategies or the MPP (marketing and product plan) [5]. Goals are defined to fulfill the business goals and scenarios describe the flow of services among agents (one being the system itself) to fulfill the goals at this level.

- Interaction level: This level contains some information about what may be done to achieve goals at the service level, and the focus is on user or system interactions with products. At this level, a goal expresses a manner of providing the service at the previous level, and a scenario describes a flow of interactions between the system and agents.

- Internal level: The internal level takes into account what the system should provide to satisfy the interactions selected at the previous level. Particularly, at the level, a scenario describes the sequence of interactions between system objects to fulfill the goal.

In the process, based on scenarios authored at each of the abstraction levels, C&V analysis determines the scenarios as common, alternative, or option. Common scenarios are what are supported by all products in a product line, and alternative and option scenarios are what differentiate them (i.e. variability). Alternative scenarios particularly represent alternative ways of fulfilling the same goal in the product line, and option scenarios represent options of fulfilling the same goal. The results of C&V analysis at the previous level lead to the relationships between goals at the next level, that is, common scenarios result into ‘AND’, alternatives into ‘Alternative-OR’ and options into ‘Optional-OR’, respectively. That is, it can be seen that the rationale for variability comes from the abstraction levels, i.e., the requirements traceability links.

In [10,12,17], the requirements elicitation process is done based on strategies. We have used four strategies, namely refinement, mandatory, alternative and option strategies to elicit PLR maximizing the value. The four discovery strategies exploit the four types of relationships identified among PLR. Additionally, based on the results of C&V analysis, the strategies are applied to the requirements elicitation process. Thus, given the goal and scenario model \((G, S, <G, S>)\):

- The refinement strategy aims to discover goals \(G_i\) at a lower level of abstraction than \(G\).
- The mandatory strategy looks for goals \(G_j\) which are ANDed to \(G\).
- The alternative strategy searches for goals \(G_k\) which are Alternative-ORed to \(G\).
- The option strategy searches for goals \(G_l\) which are Optional-ORed to \(G\).

**CASE STUDY: ENTERTAINMENT AND INFOTAINMENT**
system (EIS) in an automotive context

To demonstrate the feasibility of our approach, we select the domain of entertainment and infotainment systems (EIS) in an automotive context [18,19,20]. EIS is considered to be an immature domain. Especially, we will focus on one of the market segments for EIS in which the customers are vehicle manufacturers that include the EIS directly into the vehicle production line. To develop in-vehicle computing systems in automotive context means to provide safety and control systems needed to operate the vehicle as well as infotainment, edutainment, entertainment and mobile e-commerce services in a safe and responsible manner. The EIS market is relatively new and immature, and is changing rapidly as new devices and manufacturers continually appear.

At the business level

At first, we begin the process at the business level, that is, the business investigation to identify and understand an organization’s high-level business goals to create value. A company has projected a multi-billion-dollar market for entertainment and infotainment systems. The company intends to become a major player with two initial EIS products: a mid-end product (ME-EIS) with a product in the middle class with a few features and a high-end product (HE-EIS) with additional features. The scalability of the product is the most important goal for the product line (see “Business goals” part of Figure 5).

At the interaction level

First, the four discovery strategies help to discover goals by analyzing scenarios Sc1 and Sc1 1 in Figure 5. Especially, the results of C&V analysis at the previous level lead to the relationships between goals at this level, that is, common requirements result into ‘AND’, alternative into ‘Alternative-OR’ and option into ‘Optional-OR’. For instance, action 3 of Sc1 and action 3 of Sc1 1 lead to discovering of goals G1.3 and G1.3 1 by the refinement strategy, and the goals have ‘Alternative-OR’ relationship by the alternative strategy since those actions are alternative requirements. Second, scenarios are authored for these goals to maximize the value. Finally, as shown in the left bottom part of Figure 6, C&V analysis is done based on the scenarios.

At the service level

Figure 5 shows PLR at the business level and at the service level after C&V analysis. Based on the business investigation, candidate products for such the EIS product family are selected to maximize the value of the product line being developed, namely, ME-EIS and HE-EIS. It can be seen that these products are initial goals in the product family and this selection is the goal discovery at the service level (see the “Candidate products” part of Figure 5). And scenarios are developed to achieve the goals. Next, C&V are identified within PLR at this level. That is, not only common but also variants (i.e., alternative and option of the scenarios) are determined by C&V analysis based on the scenarios authored. As shown in Figure 5, action 3 of Sc1 and action 3 of Sc1 1 are alternative ways of fulfilling the EIS product family. Actions 1, 2 of Sc1 and action 1, 2 of Sc1 1 are common, and action 4 of Sc1 is option to fulfill the EIS product family.
At the internal level

Goals at this level express a possible way to perform an action identified in the scenarios of the previous level. For instance, ‘G1.1.1 provide a current vehicle’s location’ is a goal in the internal level. The associated scenario describes the flow of actions to achieve the goal G1.1.1. By analyzing the scenarios Sc1.1 at the interaction level (see Figure 6), Figure 7 illustrates goals and scenarios, as well as the results of C&V analysis at the internal level.

CONCLUSION AND FURTHER WORK

The approach advocated in the paper is to analyze both PLR and C&V, and provide the rationale of them by goals and scenarios, which is to create and add value to stakeholders in a product line. The EIS case has lead to a new understanding of product family development in an automotive context with the goal and scenario oriented approach. Consequently, the approach makes it possible to provide a systematic way for analyzing PLR, and providing the rationale for both PLR and C&V better meeting the organization’s goals to create stakeholders value.

Our future work includes developing the whole value-based process for product lines and a tool that helps software engineers to develop core assets of product families. Also our approach will be further extended to adequately deal with nonfunctional requirements like performance, flexibility, usability, etc., which are important for meeting an organization's business goals and needs in product family development.

REFERENCES


