Towards the Effectiveness of the SMarty Approach for Variability Management at Sequence Diagram Level

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Abstract: SMarty is a variability management approach for UML-based software product lines. It allows the identification, delimitation and representation of variabilities in several UML models by means of a UML profile, the SMartyProfile, and a systematic process with guidelines to provide user directions for applying such a profile. SMarty, in its first versions did not support sequence models. In recent studies, SMarty was extended support to these types of UML models. Existing UML-based variability management approaches in the literature, including SMarty, do not provide empirical evidence of their effectiveness, which is an essential requirement for technology transfer to industry. Therefore, this paper presents empirical evidence of the SMarty approach to recent extension to UML sequence level models.

1 INTRODUCTION

The search to increase the reuse in software development lead the creation of software product line (SPL) approach, that gained increasing attention in recent years due to the competition in the software development segment (Pohl et al., 2005). Its main objective is the derivation of products for a specific domain. Such an approach comprises a set of essential activities, such as variability management, which is a key issue for the success of SPLs. Several approaches for variability management have been proposed in the literature, as pointed out by Chen et al.(Chen et al., 2009).

Amongst existing variability management approaches there are SMarty (OliveiraJr et al., 2010) and the Ziadi et al. approach (Ziadi et al., 2003). SMarty aims to manage variabilities in UML models supported by a profile and a set of guidelines for applying such a profile to use cases, classes, components, activities and the recent extension to sequence models. Ziadi et al. approach is used to manage variabilities with an UML profile and allows explicit modeling of common and variable features supported by UML extensions for class and sequence models.

Therefore, this paper aims to identify the effectiveness of the SMarty approach comparing it to the Ziadi et al. approach by means of an experimental study.

The remainder of this paper is organized as follows: Section 2 presents essential concepts with regard to variability management, the SMarty and the Ziadi et al. approaches; Section 3 presents the planning, execution and analysis and interpretation of this experimental study; and Section 4 presents conclusion and directions for future works.

2 BACKGROUND

2.1 Variability Management

The Variability management activity is one of the essential activities in SPL (Capilla et al., 2013; Chen et al., 2009). It allows the derivation of specific products for a given domain. It brings out important benefits, such as, increases the reusability of the SPL core assets, while decreases the time to market and justify the return on investment (ROI) (Pohl et al., 2005).

There are four main concepts with regard to variability management (Pohl et al., 2005), which are: **Variability**, which is "the ability of a software or artifact to be changed, customized or configured for use in a particular context.". Variabilities can be composed of variation point, variant and variant constraints; **Variation Point**, which "identifies one or more locations at which the variation will occur."

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Thus, a variation point may take place at generic artifacts and at different levels of abstraction (Pohl et al., 2005); **Variant**, which represents the possible elements through which a variation point may be resolved; and **Variant Constraints**, which state the relationships between two or more variants to resolve a variation point or a variability.

The relevance of the variability management activity for SPLs has been gained attention of many researches, as we can see in several existing studies in the literature (Gomaa, 2004; Ziadi et al., 2003; Chen et al., 2009).

Several existing variability management approaches do not make it clear how to identify, represent and trace variabilities in different artifacts (Chen et al., 2009), especially those based on UML models. This kind of approach most takes into account stereotypes and tagged values for representing SPL variabilities. However, they fail on presenting the rationale on how to apply such stereotypes and their relationships. Industry needs evidence on the effectiveness of these approaches to make their adoption feasible.

In order to provide a more precise UML-based approach for variability management, we have been developed the SMarty approach (OliveiraJr et al., 2010; Fiori et al., 2012), which is supported by a profile and a set of guidelines for applying its stereotypes and relationships. In recent study SMarty (version 4.0) was extend to support UML sequence model (SMarty version 5.0). The SMarty extension was proposed based on two main reasons: the results of a systematic literature review of variability management approaches, which identified the lack of approaches that guarantee an identification and representation of variabilities in UML sequence models and the need for representing the dynamic aspects of a SPL by means of interaction models, as sequence diagrams do.

After proposing the sequence model extension to the SMarty approach, there is the need of identify the SMarty effectiveness, as in the study conducted in (Marcolino et al., 2013). To do so, a similar approach was chosen, throughout a systematic literature review: the Ziadi et al. approach (Ziadi et al., 2003; Ziadi and Jezequel, 2006). Ziadi et al. proposed an UML Profile with a set of stereotypes to identify variabilities in class and sequence models.

Therefore, gathering initial evidence with regard to the effectiveness of the SMarty approach was conducted by means of the current experimental study. The Next sections present the Ziadi et al. and the SMarty approaches essential concepts.

2.2 The Ziadi et al. Approach

Ziadi et al. propose one of the most representative approaches for managing variabilities in UML sequence models (Chen et al., 2009).

The Ziadi et al. approach (Ziadi et al., 2003; Ziadi and Jezequel, 2006), is supported by an UML profile, which allows its integration with UML tools to identify and represent variabilities for the following UML models: class and sequence.

There is a set of explicit meta-attributes (tagged values) and meta-classes for performing variability modeling activity. Ziadi et al. approach uses stereotypes to provide identification of variation points and variants, for class and sequence.

The stereotypes proposed by Ziadi et al. to sequence models are as follows: ≪optionalLifeline≫, used to indicate optional and alternative *lifelines*; ≪optionalInteraction≫, used to represent interactions that might or not might be present in SPL specific products; ≪variation≫, used to represent the variation point of alternative inclusive or exclusive variants; ≪variant≫, used to represent the variants of a variation point; and ≪virtual≫, used to indicate that an interaction is a virtual part. It might be redefined by another sequence diagram, and it might be represent variabilities. It is used in specific cases, in which the SPL needs to model a behavior that can be modified.

For extending the semantic for class models and sequence trough a UML profile, its stereotypes must be apply to the elements that were extended from meta-class from UML meta-model, and it represent a problem for the Ziadi proposal.

The Ziadi et al. approach uses elements, such as UML Frame. However, this element is not present in UML modeling tools, such as Poseidon 8.0[1], MagicDraw 11[2] and Astah 6[3]. The absence of such an element makes it difficult the process of identification of variabilities based on the Ziadi et al. approach as Frame is essential for representing variants of a given variation point. Variation points must not exist with any associated variants. Therefore, in a practical way, there is no support for such variability modeling in current mentioned UML tools. Despite of such an issue, the Ziadi et al. approach can be taken into consideration in this study.

[1]http://www.gentleware.com/.
[2]http://www.nomagic.com/.
[3]http://astah.net/.

2.3 The SMarty Approach

SMarty (OliveiraJr et al., 2010) is an approach for UML **S**tereotype-based **M**anagement of **V**a**r**iabili**ty** in SPL. It is composed of an UML 2 profile, the *SMartyProfile*, and a process, the *SMartyProcess*.

The ***SMartyProfile:*** contains a set of stereotypes and tagged values to represent variability in SPL models. Basically, *SMartyProfile* uses a standard object-oriented notation and its profiling mechanism, both to provide an extension of UML and to allow graphical representation of variability concepts. Thus, there is no need to change the system design structure to comply with the SPL approach.

The ***SMartyProcess:*** is a systematic process that guides the user through the identification, delimitation, representation, and tracing of variabilities in SPL models. It is supported by a set of application guidelines as well as by the *SMartyProfile* to represent variabilities.

Table 1: SMarty and Ziadi et al. Approaches Support for Sequence Diagrams.

Criterion			Approaches: SMarty (Sequence Model)	Approaches: Ziadi et al. (Sequence Model)
Support UML Model			☑	☑
UML Profile			☑	☑
Guidelines for Identification and Representation of Variability			☑	☒
Use UML Stereotypes			☑	☑
Explicit representation of	Variantion Point		☑	☑
		Optional	☑	☑
		Inclusive (OR)	☑	☒
		Exclusive (XOR)	☑	☑
	Variability		☑	☒
	Constraints between variants	Complement	☑	OCL
		Mutually Exclusion	☑	OCL
Cardinality			☑	☒
Binding time delcaration			☑	☒
Addition of new variants			☑	☒

Legend: ☑ Approach supports the concept. ☒ Approach does not support the concept.

The **SMartyProfile:** comprises the following stereotypes, which can be applied to UML use case, class, component, activity, and recent extension to sequence models, taking into account the variability concepts of Section 2.1: ≪**variability**≫; ≪**mandatory**≫, ≪**optional**≫, ≪**alternative_OR**≫ an inclusive variant; ≪**alternative_XOR**≫ a mutually exclusive variant; ≪**mutex**≫ mutually exclusion among variants; and ≪**requires**≫ the presence of another given variant.

Table 1 summarizes and compares the main features of SMarty and Ziadi et al. approaches. Note that the Ziadi approach does not support the representation of inclusive variants as well as variabilities. Ziadi et al. approach does not make it clean meta-attribute of variabilities, such as, binding time and the addition of new variants to a given variation point. These issues might lead to inconsistent products derivation.

The well-known PLUS method (Gomaa, 2004) was not taken into consideration as it does not support variability representation in sequence diagrams.

3 THE EXPERIMENTAL STUDY

This study is characterized as a quasi-experiment (Wohlin et al., 2000) that relaxes the conditions imposed by probability distributions and statistical inferences for the population. Therefore, we performed the non-equivalent grouping method, considering that the population distribution was not random (discussed in Section 3.5).

3.1 Definition

The goal of the experiment was to **compare** the Ziadi et al. and the SMarty approaches, **for the purpose of** identify the most effectiveness, **with respect to** the capability of identification and representation of variabilities in Software Product Line sequence models, **from the point of view of** software product line architects, **in the context of** master and Ph.D. students of the Software Engineering area from the Federal University of Paraná - UFPR and State University of Maring - UEM.

According to the GQM model, it was established two research questions (R.Q.) for the study:

R.Q.1 Which methodology is more effective in identify and representing variabilities in SPL sequence models?

R.Q.2 Does the prior subject SPL knowledge influence the application of the method/approach to UML sequence models?

3.2 Planning

1. **Local Context:** a SPL for Banking Transactions, proposed by Ziadi et al. (Ziadi and Jezequel, 2006) and a pedagogical SPL for Arcade Game Maker, proposed by (SEI, 2012), were taken into consideration to apply the Ziadi et al. and the SMarty approaches aiming the representation of variabilities in sequence models.
2. **Training:** subjects were trained with regard to essential concepts of SPL and variability and sequence model variability identification and rep-

resentation using Ziadi et al. UML Profile or SMarty.

3. **Pilot Project:** a pilot project was performed for evaluating the study instrumentation taking into account two lecturers of software engineering. Thus, adjustments on the instrumentation were made based on the pilot project results.

4. **Selection of Subjects:** the subjects must be graduate students, lecturers or practitioners of the software engineering area with at least minimal knowledge in modeling classes. In addition, after the training sessions, each subject must be familiar with the essential variability management concepts (Section 2.1).

5. **Instrumentation:** every subject was giving the following documents:
   - the consent term to the experimental study;
   - a characterization questionnaire, in which the subjects must indicate their academic background, area of expertise and experience, their level of experience with the UML notation and the SPL approach; and
   - the description of the Banking and Arcade Game Maker SPLs and their sequence models with no variabilities represented.

   Subjects were separated into two groups, balanced by their knowledge. One group focused on the X approach (the Ziadi et al. approach) and one group focused on the Y approach (the SMarty approach). One group was trained to identify and represent variabilities according to the X approach and the other group was trained to identify and represent variabilities according to the Y approach.

6. **Hypothesis Formulation:** the following hypothesis were tested in this study:
   - **Null Hypothesis (H_0):** both X and Y approaches are equally effective in terms of representing variabilities in sequence models. $H_0 : \mu(\textit{effectiveness(X)}) = \mu(\textit{effectiveness(Y)})$;
   - **Alternative Hypothesis (H_1):** X approach is less effective than Y approach. $H_1 : \mu(\textit{effectiveness(X)}) < \mu(\textit{effectiveness(Y)})$; and
   - **Alternative Hypothesis (H_2):** X approach is more effective than Y approach. $H_2 : \mu(\textit{effectiveness(X)}) > \mu(\textit{effectiveness(Y)})$.

7. **Dependent Variables:** the effectiveness calculated for each variability management approach (X and Y) as follows:

   $$\textbf{\textit{effectiveness(z)}} = \begin{cases} nVarC, & \text{if } nVarI = 0 \\ nVarC - nVarI, & \text{if } nVarI > 0 \end{cases}$$

   where:
   - z is the variability management approach
   - *nVarC* is the number of correct identified variabilities elements according to the z approach
   - *nVarI* is the number of incorrect identified variabilities elements according to the z approach

   A variability element might be either a variation point or a variant.

8. **Independent Variables:** the variability management approach, which is a factor with two treatments (X and Y) and the SPL, which is a factor with two treatments: Banking and Arcade Game Maker.

9. **Qualitative Analysis:** aims to evaluate the results obtained in this study with respect to the results obtained by means of descriptive statistical analysis, based on the effectiveness obtained from the resolution of the sequence variability model by each subject, according to the X and Y approaches.

10. **Random Capacity:** the selection of the subjects was not random within the universe of the volunteers which was quite restricted. The random capacity took place at the assignment of the variability management approach (X or Y) to each subject.

11. **Block Classification:** because the application of two different approaches to represent variability in class models, it was performed the random sampling, where the population was divided into two blocks, one for the X approach and one for the Y approach, with level of knowledge balanced by the characterization questionnaire.

12. **Balancing:** tasks were assigned in equal numbers to a similar number of subjects.

13. **Review Mechanism:** for reviewing the study analysis it was used the calculation of the effectiveness for each treatment.

3.3 Execution

1. **Selection of Subjects:** a total of 14 masters and Ph.D. students of the Software Engineering area were selected for this study.

2. **Instrumentation:** the main assessment tools were the Banking and Arcade Game Maker se-

quence models with variabilities represented according to the X and Y approaches. Both, the Banking and Arcade Game Maker sequence models, were distributed and ordered in equal numbers and, randomly. The subjects were warned to not change the order of SPLs and their respective resolutions.

The main task for each subject was reading and understanding the Banking and Arcade Game Maker SPLs overviews. Then, the subjects annotated variabilities in the Banking and Arcade Game Maker sequence models.

Table 2: Banking and AGM SPLs Collected Data and Descriptive Statistics: X (Ziadi et al.) and Y (SMarty) Approaches.

The X Approach (Ziadi et al.)			
Subject #	Correct Identified Variabilities	Incorrect Identified Variabilities	Effectiveness Calculation
1	19.0	13.0	6.0
2	19.0	9.0	10.0
3	4.0	28.0	-24.0
4	31.0	1.0	30.0
5	23.0	9.0	14.0
6	28.0	4.0	24.0
7	16.0	16.0	0.0
Mean	20.0	11.4	8.6
Std. Dev.	8.2	8.2	16.3
Median	19.0	9.0	10.0

The Y Approach (Smarty)			
Subject #	Correct Identified Variabilities	Incorrect Identified Variabilities	Effectiveness Calculation
1	29.0	3.0	26.0
2	32.0	0.0	32.0
3	32.0	0.0	32.0
4	32.0	0.0	32.0
5	29.0	3.0	26.0
6	32.0	0.0	32.0
7	13.0	19.0	-6.0
Mean	28.4	3.6	24.9
Std. Dev.	6.4	6.4	12.9
Median	32.0	0.0	32.0

3. **Participation Procedure:** standard procedures were adopted for each subject participation, which are:
   (a) the subject came along the place where the study was conducted;
   (b) the experimenter gives the subject a set of documents:
   - the experimental study consent term;
   - the characterization questionnaire;
   - essential concepts on variability management in SPL;
   - the description of the Banking and Arcade Game Maker SPLs; and
   - the description of main graphical elements and paths from UML sequence models.

   (c) the subject reads each given document;
   (d) the experimenter explains the given documents;
   (e) the experimenter randomly associates each subject to the X or Y approach;
   (f) the experimenter trains the subjects on the respective approach;
   (g) the subject reads and clarifies possible doubts about the subject assigned approach; and
   (h) the subject identifies and represents variabilities in the Banking and Arcade Game Maker sequence models according to his/her given approach.
4. **Execution:** collected data is presented in Table 2 and analyzed using appropriate statistical methods, which are properly discussed in Section 3.4. For each subject (“`Subject #`” column), it was collected the following data for his/her given approach: the number of correct and incorrect identified and represented variabilities; and the effectiveness calculation.

3.4 Analysis and Interpretation

Based on the results obtained by analyzing the application of the X and Y approaches to the Banking and Arcade Game Maker SPLs, the following steps were taken for answering the study research questions (Section 3.1):

- analyze and interpret the X and Y collected data (sample) by means of the Shapiro-Wilk normality test and the T Test, to validate their statistical power; and
- analyze and interpret the correlation between the effectiveness of the approaches and the subjects characterization questionnaire by means of Shapiro-Wilk normality tests and the Pearson's ranking correlation techniques.

3.4.1 Effectiveness of the Approaches (R.Q.1)

- **Collected Data Normality Tests:** the Shapiro-Wilk normality test was applied to the Banking and Arcade Game Maker samples (Table 2) providing the following results:

  The X approach (N=7):
  Banking SPL Effectiveness: mean value (μ) 2.71, standard deviation value of (σ) 3.9175, the effectiveness for the X approach for the *Banking* SPL

was p = 0.1333 for the *Shapiro-Wilk* normality test.

In the *Shapiro-Wilk* test for a sample size *(N)* 7 with 95% of significance level (α = 0.05), p = 0.1333 (0.1333 > 0.05) and calculated value of W = 0.8538 > W = 0.8030, the sample is considered normal.

Arcade Game Maker SPL Effectiveness: mean value (μ) 5.85, standard deviation value (σ) 14.4956, the effectiveness for the X approach for the *Arcade Game Maker* SPL was p = 0.4813 for the *Shapiro-Wilk* test.

In the *Shapiro-Wilk* test, for (α = 0.05), p = 0.4813 (0.4813 > 0.05) and calculated value W = 0.9215 > W = 0.8030, the sample is considered non-normal.

Total Effectiveness: mean value (μ) 8.57, standard deviation value of (σ) 16.3432, the total effectiveness for X approach was p = 0.9456 for the *Shapiro-Wilk* test.

Finally, for (α = 0.05), p = 0.9456 (0.9456 > 0.05) and calculated value of W = 0.9456 < W = 0.8030, the sample is considered normal.

***The Y Approach (N=7)*:**

Banking SPL Effectiveness: mean (μ) 4.71, standard deviation of (σ) 3.1036, the effectiveness for the Y approach for the *Banking* SPL was p = 0.0111 for the *Shapiro-Wilk* test.

In the *Shapiro-Wilk* test, for a sample size of 7 with 95% of significance level (α = 0.05), p = 0.0111 (0.0111 < 0.05) and calculated value W = 0.7444 > W = 0.8030, the sample is considered non-normal.

Arcade Game Maker SPL Effectiveness: mean (μ) 20.14, standard deviation value of (σ) 10.3568, the effectiveness for the Y approach for *Arcade Game Maker* SPL was p = 0.00003 for the *Shapiro-Wilk* test.

In the *Shapiro-Wilk* test, for (α = 0.05), p = 0.00003 (0.00003 < 0.05) and calculated value of W = 0.5276 > W = 0.8030, the sample is considered normal.

Total Effectiveness: mean (μ) 24.8, standard deviation (σ) 12.8666, the total effectiveness for the Y approach was p = 0.0002 for the *Shapiro-Wilk* test.

Finally, for (α = 0.05), p = 0.0002 (0.0002 > 0.05) and calculated value W = 0.5988 > W = 0.8030, the sample is considered normal.

- **T-test:** this kind of test can be applied for both independent and paired samples (Wohlin et al., 2000). In the case of this study, Sample X and Sample Y are independent. As each sample size is less than 30 and both samples are normal, it was defined the following hypothesis:

  – **Null Hypothesis (H_0):** approach X has the same effectiveness of approach Y.
  H_0 : μ(*effectiveness(X)*) - μ(*effectiveness(Y)*) = 0;

  – **Alternative Hypothesis (H_1):** approach Y is more effective than approach X.
  H_1 : μ(*effectiveness(Y)*) - μ(*effectiveness(X)*) > 0.

  First we obtained the value of T, which allows the identification of the range entered in the statistical table t (*student*). This value is calculated using the average of Sample Y (μ1 = 8.5714) and Sample X (μ2 = 24.8571), standard deviation value of both (σ1 = 16.3432 and σ2 = 12.8666), and the sample sizes (N = 7). It was obtained the value $t_{calculated} = 8.4014$.

  By taking the sample size (N = 7), we obtained the degree of freedom (df), which combined to the t value indicates which value of p in the t table must be selected. The p value is used to accept or reject the T-test null hypothesis (H_0).

  By searching the index $df = 12$ and defining the value t at the t table (*student*), was found a value for critial t of 2.1790 ($t_{critial} = 2.1790$), with a significance level (α) of 0.05. Thus, comparing the $t_{critial}$ with the $t_{calculated}$ the null hypothesis H_0 must be rejected and (H_1) must be accepted ($t_{calculated}(8.4014) >= t_{critial}(2.1790)$).

  Therefore, based on the result from the T test, the null hypothesis (H_0) of this experimental study (Section 3.2) must be rejected and the alternative hypothesis must be accepted. It means that the Y approach (SMarty Approach) is more effective than the X approach (Ziadi et al. Approach) for representing variability at SPL sequence level for this experimental study.

3.4.2 Correlation Between the Approaches Effectiveness and the Subjects Variability Characterization (R.Q.2)

- **Knowledge Level in SPL for Subjects from X Approach:** sample size of (N) 7, with mean (μ) 2.5, standard deviation value of (σ) 0.9574, the knowledge level of subjects was p = 0.4817 for the *Shapiro-Wilk* test.

  In the *Shapiro-Wilk*, for a sample size of 7 with 95% of significance level (α = 0.05), p = 0.4817 (0.4817 > 0.05) and calculated value W = 0.9215 less than W = 0.8030 the sample is considered normal.

- **Knowledge Level in SPL for subjects from Y Approach:** sample size of (N) 7, with mean value (μ) 4.5, standard deviation of (σ) 0.5000, the knowledge level p = 0.4817 for the *Shapiro-Wilk* test.

  In this *Shapiro-Wilk* test, for a sample size of 7 with 95% of significance level (α = 0.05), for the Y approach, p = 0.4817 (0.4817 $<$ 0.05) and calculated value W = 0.9215 greater than W = 0.8030, the sample is considered normal.

- **Pearson's Correlation:** this technique was applied to identify whether there is a correlation between the effectiveness of each approach (X and Y) and the level of knowledge of the subjects, for parametric values. The values from Table 1 were applied on the equation 1 that shows the formula to calculate the Pearson's ρ correlation.

$$r = \frac{n(\Sigma ab) - (\Sigma a)(\Sigma b)}{\sqrt{[n(\Sigma a^2) - (\Sigma a)^2][n(\Sigma b^2) - (\Sigma b)^2]}} \quad (1)$$

The calculation for each correlation, according to the approach and SPLs is shown in Equations 2, 3.

$$r(Corr.1) = \frac{994-60*16}{\sqrt{13088*52}} = 0.0412 \quad (2)$$

$$r(Corr.2) = \frac{4774-174*26}{\sqrt{8112*52}} = 0.3849 \quad (3)$$

Thus, it was obtained the following values for r as well as the classification scale by Pearson and (Higgins and Ed.D., 2005) shown in Figure 1:

	Coefficient, r	
Strength of Association	Positive	Negative
Weak	0.1 to 0.29	-0.1 to -0.29
Moderate	0.3 to 0.49	-0.3 to -0.49
Strong	0.5 to 1.0	-0.5 to -1.0

Figure 1: Pearson's Correlation Scale.

- *Result correlation for X and Knowledge Level in SPL*: $r = 0.0412$ - Weak positive relationship;

Table 3: Pearson's correlation for knowledge level of subjects for the X and Y approaches.

The X Approach (Ziadi et al.)			*The Y Approach (SMarty)*		
#	Effectiveness	Knowledge Level in SPL	#	Effectiveness	Knowledge Level in SPL
1	6	1	1	26	4
2	10	1	2	32	5
3	-24	2	3	32	4
4	30	2	4	32	5
5	14	3	5	26	2
6	24	3	6	32	3
7	0	4	7	-6	3

- *Result correlation for Y and Knowledge Level in SPL*: $r = 0.3849$ - Moderate positive relationship.

Analyzing the results obtained by means of the Pearson correlation, it was observed that, for the X approach the knowledge level in SPL of each subject there is a weak positive relationship, and for the Y approach, there is a moderate positive relationship. It means that the greater the value for the correlation, the greater is the influence of the previous knowledge on SPL and variability to the application of a given approach. Therefore, SMarty was more influenced by its subjects knowledge level than Ziadi et al.

3.5 Validity Evaluation

- **Threats to Conclusion Validity:** the major concern is the sample size, which must be increased in prospective studies.

- **Threats to Construct Validity:** effectiveness is calculated based on the ability of the subjects in modeling variability by taking into consideration the X and Y approaches and the Banking and Arcade Game Maker SPLs. The independent variable `variability modeling approach` is guaranteed by the pilot project undertaken.

- **Threats to Internal Validity:** we dealt with the following issues: **Differences among subjects** - as we took into consideration a small sample, variations in the subject skills were reduced by performing a training session and the tasks in the same order. The subjects experience had approximately the same level for UML modeling and variability concepts; **Fatigue effects** - on average, the experiment lasted for 20 minutes, thus fatigue was considered not relevant; and **Influence among subjects** - it could not be really controlled. Subjects took the experiment under supervision of a human observer. We believe that this issue did not affect the internal validity.

- **Threats to External Validity:** two threats were detected: **Instrumentation** - failing to use real sequence models, as the Baking and the Arcade Game Maker SPLs are not commercial. More experimental studies must be conducted using real SPLs, developed by industry; and **Subjects** - masters and Ph.D. students of Software Engineering were selected. However, more experiments taking into account industry practitioners must be conducted, allowing to generalizing the study results.

4 CONCLUSION AND FUTURE WORK

Industry needs that the scientific community test existing and new technologies, such as SMarty, identifying their effectiveness in order to provide evidence of such new technologies effectiveness allowing them to be adopted by companies. Such evidence is essential for technology transferring, as well as for return on investment.

The experimental study presented in this paper demonstrates the ability to use variability management approaches. Their effectiveness was analyzed in order to provide a means to companies on selecting the most appropriate for variability management of UML-based SPLs. The experimental study allows analyzing the effectiveness of the SMarty and Ziadi et al. treatments for modeling variability in sequence diagram models. Two SPLs were set as independent variables: a SPL for banking and the SEI AGM SPL.

The *Shapiro-Wilk* normality test was applied to the samples, collected by the effectiveness formula. Both samples were considered normal, thus it was applied the parametric T-test. This test analyzed the effectiveness of the Ziadi et al. and the SMarty approaches. Then, the correlation of the subjects' level of knowledge in SPL and variability was performed based on the *Pearson* technique, which shown that knowledge had a moderate influence on the application of the SMarty approach and a weak influence on the application of the Ziadi et al. approach.

The obtained results provided evidence of the SMarty effectiveness for modeling variability in UML sequence models, taking into account the Banking and the AGM SPLs.

This paper is limited with regard to: (i) the reduced sample size, which is a major issue in experimental software engineering (Kitchenham et al., 2013); and (ii) the lack of real SPLs and industry practitioners for participating in the study conduction.

New experimental studies and replications must be planned and conducted to make it possible to reduce the threats, increasing the effectiveness of SMarty and generalizing the results. As new experiments, we are: (i) planning a replication of this study to corroborating the obtained results; (ii) planning an experiment for effectiveness analysis of SMarty for sequence models using real SPLs and practitioners from industry; (iii) planning an external replication which will be conducted by a different experiment team in order to corroborate the obtained results.

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