Software Product Line Traceability and Product Configuration in Class and Sequence Diagrams: An Empirical Study

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Abstract: A set of systems that share common and variable parts is called a Software Product Line (SPL). These kind of systems are usually part of the same market segment. Their elements that vary are what allow the diversification among products from the same family, thus managing variability is an important issue of SPL engineering. There are few studies in the literature that evaluate and compare approaches to SPL variability management in UML-based SPLs. In this work, two of the existing approaches, SMarty and Ziadi et al., are compared throughout an experiment to verify: the effectiveness in configuring products based on UML class and sequence diagrams; the influence of the participants knowledge on UML, SPL and variability in the effectiveness results; and how traceability is performed in each approach. Results show the SMarty approach is statically superior with relation to Ziadi et al. for the effectiveness at configuring products with class and sequence diagrams. Regarding the knowledge level needed to a better effectiveness, SMarty demands less knowledge than Ziadi et al. In addition, Ziadi et al. provides no means to round-trip trace variabilities in class and sequence diagrams, thus SMarty was previously designed to allow it.

1 INTRODUCTION

According to Almeida (2019), several techniques exist to allow software reuse, establishing actions and strategies to be taken to ensure compliance with standards such as: software product lines, application frameworks, design standards, and program libraries.

Software Product Line (SPL) is an approach that is constantly growing since the adoption of a successful SPL brings out several advantages to the organization, such as productivity improvement, development time, product quality and customer satisfaction (Clements and Northrop, 2001; Linden et al., 2007).

For the successful adoption of SPL, managing variability becomes essential. In the SPL context, variability represents a subset of all possible choices to generate specific products. Variation points and variants are used to define SPL variabilities. According to Chen and Ali Babar (2011), variation points describe the specific location where differences occur in systems, and variants represent the different possibilities to resolve a variation point.

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In the existing literature, we may highlight consolidated UML-based SPL variability management approaches, such as PLUS (Gomaa, 2004) and the Ziadi et al. approach (Ziadi and Jezequel, 2006).

Chen and Ali Babar (2011), Galster et al. (2014), and Raatikainen et al. (2019) point out such approaches have not been properly experimented, using rigorous scientific methods. In a systematic review by Ahnassay et al. (2014), the results show that a large part of the empirical assessments on SPL was not adequately designed or reported.

We previously compared the SMarty approach to other existing UML-based variability management approaches as: in Nepomuceno et al. (2020) for use cases and classes; and in Nepomuceno et al. (2020) for classes and components. Therefore, in this work[1], we want to answer the following research question: ***"Is the SMarty approach more effective at configuring specific products from UML-based SPL at class and sequence diagrams level compared to the Ziadi et al. approach?"***.

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2 BACKGROUND AND RELATED WORK

2.1 The Ziadi et al. Approach

The Ziadi et al. approach (Ziadi and Jezequel, 2006) is composed of an UML 2.0 profile with a set of explicit tagged values and metaclasses to annotate sequence and class diagrams elements for representing variability. The stereotypes proposed by Ziadi et al. are as follows: <<**optionalLifeline**>> used to represent alternative or optional lifelines in sequence diagrams; <<**optionalInteraction**>> used to represent optional interactions in sequence diagrams; <<**optional**>> used to represent optional elements in class diagrams, such as classes and packages; <<**variation**>> used to represent variation points in sequence and class diagrams; <<**variant**>> used to represent variants in class and sequence diagrams; <<**virtual**>> used to indicate when an interaction represents a specific situation in which the behavior of a sequence diagram can be represented by another sequence diagram.

Figure 1 represents a sequence diagram example. The highlighted elements are possible products configured from the complete diagram.

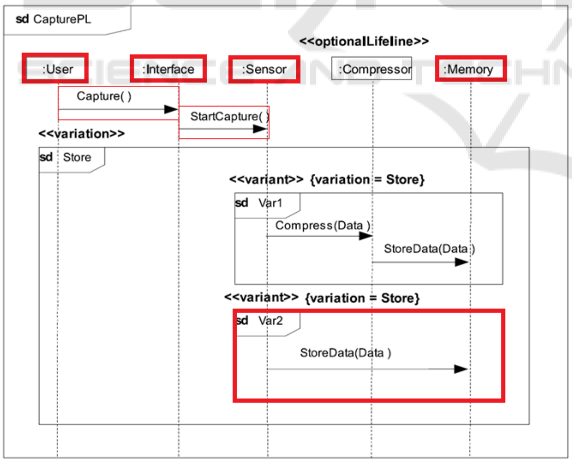

Figure 1: A sequence diagram modeled according to Ziadi et al.

The Ziadi et al. approach does not offer any support for tracking elements from class to sequence diagrams and vice-versa.

2.2 The SMarty Approach

SMarty is composed of a UML profile, the SMartyProfile, and a process, the SMartyProcess (OliveiraJr et al., 2010). The UML profile is composed of a set of stereotypes and tagged-values as follows: <<**variability**>>**:** represents variabilities in an UML note. It has the following attributes: name: name used to refer to a variability; minSelection: minimum number of variants selected to solve a variation point or variability; maxSelection: maximum number of variants selected to solve a variation point or variability; bindingTime: moment of variability resolution; variants: collection of instances associated with variability; realizes+: collection of variability names of higher level diagrams; and realizes-: collection of variability names of lower level diagrams. <<**variationPoint**>>**:** stereotype of variation point; <<**mandatory**>>**:** represents this variant must necessarily be present in any product; <<**optional**>>**:** represents an optional variant; <<**alternative_OR**>>**:** indicates the existence of a group of inclusive variants. Different combinations of inclusive variants can be selected for the resolution of a variation point or variability; <<**alternative_XOR**>>**:** indicates the existence of a group of exclusive variants. Only one variant of this group can be selected for the resolution of a variation point or variability; <<**mutex**>>**:** represents the mutually exclusive relationship between variants; <<**requires**>>**:** represents a complement relationship between two variants.

Figure 2 represents a sequence diagram example. The highlighted elements are possible products configured from the complete diagram.

Traceability among class and sequence elements and vice-versa in SMarty is performed using the `realizes+` and `realizes-` meta-attributes of the <<variability>> stereotype.

2.3 Related Work

As far as we know, based on a non-systematic search and the works of Ahnassay et al. (2014), Chen and Ali Babar (2011), Galster et al. (2014), and Raatikainen et al. (2019) there is no study in the literature directly related to experimental comparison among UML-based variability management approaches with regard to product configuration and traceability in class and sequence diagrams. However, our research group has developed several experiments to show the effectiveness of SMarty.

Marcolino et al. (2013) conducted an experiment in 2013 comparing the SMarty approach with the PLUS (Gomaa, 2004) method in relation to the identification and resolution of variability in use case diagrams, in which SMarty provided better results than the PLUS method.

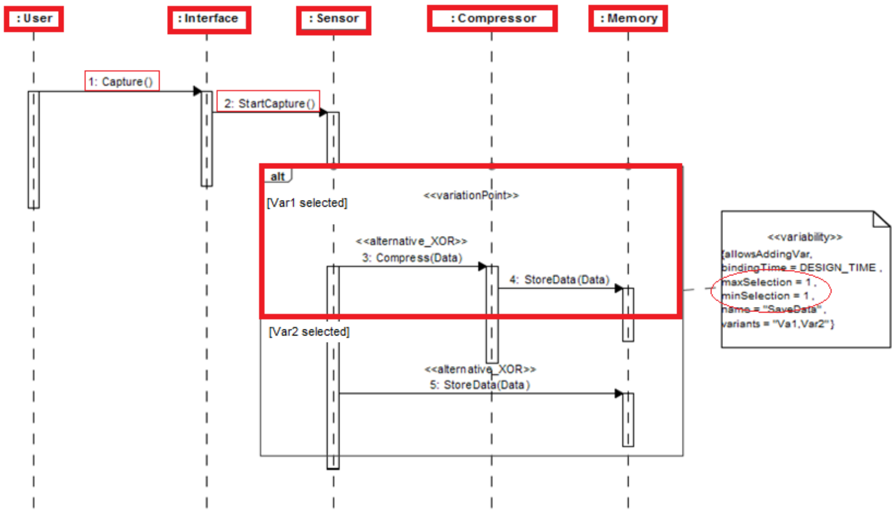

Figure 2: A sequence diagram modeled according to the SMarty approach.

A year later, a new experiment was conducted by Marcolino et al. (2014a) comparing SMarty and Ziadi et al. approaches in sequence diagrams. As a result, SMarty also provided more effectiveness results at identifying and resolving variabilities.

In another experiment in 2014, Marcolino et al. (2014b) compared SMarty and PLUS regarding the identification and resolution of variability in class diagrams. In this evaluation, the PLUS method provided better effectiveness results.

Two other experiments were conducted by Marcolino et al. (2017) and Marcolino and OliveiraJr (2017) in 2017, which compared SMarty and PLUS for a class diagram. In the first experiment, there was no statistical difference between the effectiveness samples in relation to the ability to interpret and configure the correct products. In the second, PLUS provided better results.

3 EMPIRICAL STUDY

This study[2] is characterized as a quasi-experiment, as the selection of participants was not randomized based on the fact that the participants were chosen for convenience.

The **goal of this experiment** is to compare the approaches Ziadi et al. and SMarty, **with the purpose of** identifying which is more effective regarding the configuration of specific products in sequence and class diagrams, thre relevance of the knowledge of each participant, and the traceability capacity of each approach **from the point of view of** researchers in the role of SPL architects, **in the context of** undergraduate and graduate students who have previously knowledge about UML, SPL and variability.

We defined the following research questions for this study: **RQ1:** *Which approach is more effective for deriving specific product configurations from sequence and class diagrams?*; **RQ2:** *What is the influence of the participants level of knowledge in configuring specific products from sequence and class diagrams?*; and **RQ3:** *Which approach is more effective in tracing elements from class to sequence diagrams and vice-versa?*

3.1 Planning

This study can be characterized on the following dimensions: **Process:** for eight participants, the process was online. We provided all instruments as a link on the Google drive and the responses were returned by email. For 22 participants, we applied the experiment offline in different days, according to the availability of each participant; and **Participants:** all participants were undergraduate or graduated students. The profile description of participants knowledge is shown in Table 1.

The selection of participants was non-probabilistic, not randomized based on the fact that participants were chosen for convenience.

Thirty people participated in the experimental evaluation. Such participants were undergraduate or graduate students in Computer Science and Computer Engineering, some with expertise in the industry.

The participants received a set of documents, which are:

[2]Data of this study are available at https://doi.org/10.5281/zenodo.4304279

Table 1: Knowledge level of participants.

Part. ID	Knowledge		Education	Exper. in Industry?	Experience (months)
	UML	SPL/ Variab.			
1	Basic	Basic	Masters St.	No	36
2	Moderate	Have read	Masters St.	Yes	36
3	Moderate	Basic	Masters St.	No	50
4	Moderate	Basic	Masters St.	No	48
5	Basic	Have read	Bachelor	Yes	25
6	Basic	None	Bachelor	Yes	12
7	Basic	None	Bachelor	Yes	30
8	Moderate	Have read	Bachelor	No	10
9	Basic	Have read	Bachelor	No	60
10	Moderate	Have read	Bachelor	No	36
11	Basic	None	Bachelor	No	8
12	Basic	Have read	Bachelor	Yes	36
13	Basic	Have read	Bachelor	Yes	30
14	Basic	Have read	Bachelor	Yes	48
15	Moderate	None	Bachelor	No	48
16	Basic	None	Bachelor	No	24
17	Moderate	Have read	Bachelor	Yes	20
18	Moderate	Have read	Bachelor	Yes	15
19	Moderate	None	Bachelor	Yes	36
20	Moderate	Have read	Bachelor	No	36
21	Basic	None	Bachelor	No	24
22	Basic	None	Bachelor	Yes	34
23	Basic	None	Bachelor	Yes	40
24	Moderate	None	Bachelor	No	36
25	Moderate	None	Bachelor	No	36
26	Basic	None	Bachelor	No	36
27	Moderate	None	Masters St.	No	36
28	Basic	None	Bachelor	Yes	60
29	Basic	None	Bachelor	No	36
30	Basic	None	Bachelor	Yes	26

- **Informed Consent Term (ICT):** containing the main information about the experiment, such as: confidentiality, procedures and benefits. Such document allowed the participants to make their decision about participation or not in the research in a fair way;
- **Characterization Questionnaire:** applied to participants to analyze the level of knowledge and experience on UML, SPL and variability;
- **Theoretical Synthesis:** to facilitate the participant to find the information on the experiment, this document was divided into three sections. The first with the main concepts of Software Product Lines and the second with the general description of the AGM SPL. As the participants were divided into two blocks (one block for each approach), the third section of this document, which comprised information about the approaches, was different for each group. The division was carried out by sending different links to each group of participants, as follows:
  - **Block with Ziadi et al.:** comprised a summary of the concepts of the Ziadi et al. approach, as well as their stereotypes and examples. This approach in the documentation was represented by X;
  - **Block with SMarty:** concepts about the SMarty approach, its stereotypes and examples. This approach was identified as Y.
- **Videos (in Portuguese):** with the explanation of SPL and the approaches and examples.

We defined the following hypotheses as follows:

- for effectiveness in sequence diagrams:
  - Null Hypothesis ($H0_{eff\_seq}$): there is no significant difference in the effectiveness between SMarty and Ziadi et al. at configuring specific SPL products from sequence diagrams.
    $\mathbf{H0}_{eff\_seq}$: **μ(eff_seq(SMarty)) = μ(eff_seq(Ziadi et al))**
  - Alternative Hypothesis ($H1_{eff\_seq}$): there is a significant difference in the effectiveness between SMarty and Ziadi et al. at configuring specific SPL products from sequence diagrams.
    $\mathbf{H1}_{eff\_seq}$: **μ(eff_seq(SMarty)) $\neq$ μ(eff_seq(Ziadi et al))**
- for effectiveness in class diagrams:
  - Null Hypothesis ($H0_{eff\_cls}$): there is no significant difference in the effectiveness between SMarty and Ziadi et al. at configuring specific SPL products from class diagrams.
    $\mathbf{H0}_{eff\_cls}$: **μ(eff_cls(SMarty)) = μ(eff_cls(Ziadi et al))**
  - Alternative Hypothesis ($H1_{eff\_cls}$): there is a significant difference in the effectiveness between SMarty and Ziadi et al. at configuring specific SPL products from class diagrams.
    $\mathbf{H1}_{eff\_cls}$: **μ(eff_cls(SMarty)) $\neq$ μ(eff_cls(Ziadi et al))**

We defined the following variables for this study:

- **Independent Variables:** the `variability management approach`, which is a factor with two treatments: SMarty and Ziadi et al., and a prefixed variable, `the AGM SPL`;
- **Dependent Variables:** the `effectiveness` on correctly configuring products, the `influence of the participants knowledge` on the observed value of effectiveness, and the `traceability capability` of each approach.

To calculate effectiveness we considered the following equation:

Effectiveness (z) = nVarC/Total

Where:

- z = the approach;
- nVarC = number of variabilities correctly resolved; and
- Total = number of variabilities of a given diagram.

We calculated the influence of each participant knowledge using a correlation between the five levels of knowledge in the Characterization Questionnaire

(Likert Scale) and the value obtained for the effectiveness for each participant.

We ran a pilot project to a set of Master's students in the area of software engineering at the State University of Maringá with knowledge in managing variability in SPL.

From the application of this project, several issues could be corrected and some changes to improve the study instrumentation were made.

The participants answers of the pilot project were discarded for the final set of responses on this study.

3.2 Operation

Thirty students participated in this study. Each of the participants configured two specific products of the AGM SPL: one from the sequence diagram; and one from the class diagram.

The period of the experiment was one month, with several days for face-to-face application of the experiment according to the availability of each participant and with the same period for participants who performed the experiment online.

The group of participants was divided according to the approach received by each participant. The division was done at random. Each group received a document identifying the tasks to perform. Half of the group configured products from an AGM SPL class diagram, while the other half did it from a sequence diagram.

3.3 Analysis and Interpretation

3.3.1 Effectiveness at Configuring Products (RQ1)

The results collected from the configuration of the products by each participant are shown in Table 2, which refers to Ziadi et al. and SMarty. Such table lists information on the correct resolved variabilities (Corr), the total number of variability for a given diagram (Total), and the effectiveness (Eff) of each approach. In addition, descriptive statistics is shown in such table. A correct modeled variability element means it strictly follows the semantic meaning of variability, variation points and variants.

Normality Test. We applied the Shapiro-Wilk test to the SMarty and Ziadi et al. effectiveness samples for class and sequence diagrams.

We can observe all samples obtained p < (α = 0.05), therefore, they do not follow a normal distribution: Ziadi et al. for class diagram (N=15): p = 0.0071; Ziadi et al. for sequence diagram (N=15):

Table 2: values observed with Ziadi et al. and SMarty for class and sequence diagrams.

Class							
Ziadi et al.				**SMarty**			
Part. ID	**Corr**	**Total**	**Eff**	**Part. ID**	**Corr**	**Total**	**Eff**
1	6	10	0.6	2	10	10	1.0
3	10	10	1.0	4	10	10	1.0
5	9	10	0.9	6	10	10	1.0
7	7	10	0.7	8	8	10	0.8
9	8	10	0.8	10	10	10	1.0
11	6	10	0.6	12	9	10	0.9
13	7	10	0.7	14	10	10	1.0
15	10	10	1.0	16	10	10	1.0
17	10	10	1.0	18	9	10	0.9
19	10	10	1.0	20	10	10	1.0
21	8	10	0.8	22	10	10	1.0
23	7	10	0.7	24	10	10	1.0
25	10	10	1.0	26	9	10	0.9
27	10	10	1.0	28	10	10	1.0
29	6	10	0.6	30	9	10	0.9
Mean	8.22	-	0.82	**Mean**	9.6	-	0.96
Median	8	-	0.80	**Median**	10	-	1.00
St. Dev.	1.66	-	0.16	**St. Dev.**	0.63	-	0.06

Sequence							
Ziadi et al.				**SMarty**			
Part. ID	**Corr**	**Total**	**Eff**	**Partic**	**Corr**	**Total**	**Eff**
1	6	10	0.6	2	10	10	1.0
3	9	10	0.9	4	8	10	0.8
5	7	10	0.7	6	9	10	0.9
7	7	10	0.7	8	10	10	1.0
9	6	10	0.6	10	9	10	0.9
11	7	10	0.7	12	10	10	1.0
13	7	10	0.7	14	9	10	0.9
15	10	10	1.0	16	8	10	0.8
17	9	10	0.9	18	10	10	1.0
19	10	10	1.0	20	9	10	0.9
21	7	10	0.7	22	10	10	1.0
23	8	10	0.8	24	10	10	1.0
25	8	10	0.8	26	9	10	0.9
27	7	10	0.7	28	9	10	0.9
29	7	10	0.7	30	8	10	0.8
Mean	7.66	-	0.76	**Mean**	9.20	-	0.92
Median	7	-	0.70	**Median**	9	-	0.90
St. Dev.	1.29	-	0.12	**St. Dev.**	0.77	-	0.07

***Corr** = # of correct resolved elements, **Eff** = Effectiveness*

p = 0.02453; SMarty for class diagram (N=15): p = 0.00011; and SMarty for sequence diagram (N=15): p = 0.0043.

Hypothesis Test. Based on the non-normality of samples, we decided to apply the Mann-Whitney-Wilcoxon hypothesis test for the samples to indicate whether there is a significant difference between them according to the hypotheses established in Section 3.1, as follows:

- **For Class Diagram Effectiveness Samples:** the calculated value for p was 0.0299 (< α = 0.05). Therefore, we could reject $H0_{eff\_cls}$. It means there is a significant difference between the effectiveness of Ziadi et al. and SMarty samples for effectiveness in configuring products from class diagrams. By analyzing Table 2 we can observe better results for SMarty compared to Ziadi et al.;
- **For Sequence Diagram Effectiveness Samples:** the value of p calculated in the test was 0.001846 (< α = 0.05). Thus, we could reject $H0_{eff\_seq}$. It means there is a significant difference between the

effectiveness of Ziadi et al. and SMarty samples for effectiveness in configuring products from sequence diagrams. By analyzing Table 2 we can observe better results for SMarty compared to Ziadi et al.

Effect Size. We calculated the effect size of each hypothesis test to confirm the strength of respective samples, as follows:

- **For Class Diagram Effectiveness:** the Cohen d test was applied and we obtained -1.05, which indicates a large difference between the samples for class diagrams.
- **For Sequence Diagram Effectiveness:** for the sequence diagram, the Cohen test returned the value -1.44, which indicates a large difference between the samples of effectiveness in the configuration of products from sequence diagrams.

3.3.2 Correlation between Effectiveness and Participants Knowledge Level (RQ2)

In this section, we want to check whether there is a correlation between the effectiveness and the participant level of knowledge. To do so, we used the Spearman's correlation technique as we performed a conversion of nominal scales to discrete values regarding the participant knowledge.

We then found the following values for each diagram:

- **For Class Diagrams:**
  - Ziadi et al.: $\rho = 0.77$ a strong positive correlation;
  - SMarty: $\rho = 0.27$ a weak positive correlation.
- **For Sequence Diagrams:**
  - Ziadi et al.: $\rho = 0.66$ a strong positive correlation;
  - SMarty: $\rho = 0.05$ a weak positive correlation.

We understand the lower the correlation ρ value, the lesser the influence of the participant knowledge on the obtained effectiveness. Therefore, SMarty obtained better results than Ziadi et al. as the former demands less previous knowledge to configure products and to trace variabilities in both class and sequence diagrams. This is particularly important to SMarty newcomers to comprehend its syntax and semantics for modeling variability in UML-based SPLs.

3.3.3 Traceability (RQ3)

As the Ziadi et al. approach has no traceability mechanisms as mentioned in Section 2.1, we analyzed such mechanisms in SMarty.

To do so, we defined two likert-scaled questions to the experiment participants who used the SMarty approach:

- **Question #1:** Assuming that in a product configuration the features related to the `Game Sprite` are excluded from the class diagram, can you observe/identify the respective changes/impacts in the sequence diagram?.
- **Question #2:** If **Play Game** does not exist in the sequence diagram, can you observe/identify the respective changes/impacts in the class diagram?

We summarize the answers in Table 3.

Table 3: SMarty round-trip traceability to/from class and sequence diagrams.

Question #1: Class to Sequence		
Likert Labels	**Count**	**Percentage (%)**
I totally agree	8	53.33
I partially agree	5	33.33
I partially disagree	2	13.33
I totally disagree	0	0.00
Total	**15**	**100.0**

Question #2: Sequence to Class		
Likert Labels	**Count**	**Percentage (%)**
I totally agree	6	40.00
I partially agree	5	33.30
I partially disagree	3	20.00
I totally disagree	1	6.70
Total	**15**	**100.0**

As observed in Table 3, 13 (86.66%) participants agree changes can be traced to sequence diagrams when a related variability element is modified in a class diagram by using the <<variability>> attribute `realizes-`. We assume, sequence diagrams are lower abstraction level than class diagrams.

The same conclusion is valid for tracing elements from sequence to class diagrams as 11 (73.33%) participants could observe/identify such changes by means of the attribute `realizes+`.

Based on these results, we understand traceability in SMarty is promising, thus we need to reach 100% satisfaction of its users.

3.4 Threats to Validity

We can make considerations regarding the internal validity of this experiment, as follows: all participants were students, therefore there were no advanced skills of the group; the participants training has leveled the knowledge regarding SPL and variability, thus, we consider the participants answers valid and significant.

We detected certain threats related to the instrumentation. The AGM diagrams are not from an actual SPL. In addition, they are relatively simple to understand. Therefore, in further studies, actual and more complex SPLs must be considered to reduce such threats.

The level of knowledge of the participants can also be a threat, as some have more knowledge than others on related topics (SPL and variability).

The feasibility of the study and the instrumentation were initially tested with a pilot project to analyze whether they are suitable to be applied in the real study, and consequently not to invalidate the experiment. As for the level of knowledge, the participants received training on the concepts of SPL, variability, SMarty, and Ziadi et al., thus we understand that they obtained the necessary understanding to configure the products and to answer the SMarty-related traceability questions.

4 DISCUSSION OF RESULTS

4.1 Effectiveness Discussion

Observing the results of this study, we note a great difference between samples in terms of effectiveness.

Analyzing the **results on class diagrams**, SMarty had a mean of effectiveness of 0.96, a standard deviation of 0.06 and a median of 1.0, while Ziadi et al. obtained a mean of 0.82, a standard deviation of 0.16 and a median of 0.8. SMarty participants configured 10 products with 100% effectiveness, which represents more than half of the sample (median = 1.0). On the other hand, Ziadi et al. obtained only six products totally correctly configured, which means less than 50% of the sample (median = 0.8).

Although SMarty had better results than Ziadi et al. for class diagrams effectiveness, SMarty participants experienced partially wrong configuration of certain products, which indicates a lack of total comprehensibility of the configuration process of the approach.

In relation to the **sequence diagram**, SMarty obtained an effectiveness mean of 0.92, a standard deviation of 0.07 and a median of 0.9, whereas Ziadi et al. obtained a mean of 0.76, a standard deviation of 0.12 and a median of 0.7. SMarty participants configured six products with 100% effectiveness, which represents less than half of the sample (median = 0.9). Ziadi et al. obtained only two products totally correctly configured, which means much less than 50% of the sample (median = 0.7).

We understand sequence diagrams are more difficult to understand and to configure products with both approaches. Comparing both approaches, SMarty obtained way better results than Ziadi et al. However, especially for SMarty, this result corroborates the conclusion on the class diagrams about the lack of guidelines to support its configuration process.

All of these results provide evidence on the advantage of SMarty over Ziadi et al. We assume participants who used SMarty had better results because:

- **SMarty provides a process to guide the user on representation and identification of variability**;
- **SMarty provides several stereotypes for class and sequence diagrams, not available in Ziadi et al., which may make product configuration easier**.

4.2 Influence of Participant Previous Knowledge

In this research question, we analyzed which approach had the least influence of the participants prior knowledge. Therefore, we correlated the effectiveness obtained to the level of knowledge.

When analyzing the correlation of the **class diagrams**, SMarty had ρ value 0.27 and Ziadi et al. 0.77. With regard to Ziadi et al., a same knowledge tends to lead to a specific effectiveness value at configuring products. It means, the participant knowledge highly determines his/her effectiveness. On the other hand, in the SMarty approach, there is no tendency a same knowledge to determine the effectiveness. For SMarty, it is important as it provides numerous stereotypes Ziadi et al. does not, as well as SMarty provides a process to identify and represent variabilities, which may influence the effectiveness at configuring products.

With relation to **sequence diagrams**, SMarty had ρ value 0.05 and Ziadi et al. 0.66. As SMarty had a way less correlation ρ value than Ziadi et al., the same rationale can be used to interpret their results.

Therefore, we can summarize the results as follows: **the participant knowledge seems to be irrelevant to SMarty at configuring product from both class and sequence diagrams**.

4.3 Traceability Results

We analyzed traceability for SMarty in a round-trip flavor, from: class to sequence diagrams; and sequence to class diagrams.

From **class to sequence diagrams** 86.66% of participants agree with SMarty support at identifying and tracing the impacts at the sequence diagram level when changes are made at the class level. This means the majority of participants really comprehend the

SMarty mechanism to trace variabilities from a higher abstraction level diagram (class) to a lower level diagram (sequence) by means of the <<variability>> attribute `realizes-`. However, it seems there were certain issues making it difficult to a small portion (13.33%) of the participants to trace variabilities.

With regard to **sequence to class diagrams**, 73.3% of participants agree with SMarty support at identifying and tracing the impacts at the class diagram level when changes are made at the sequence level. Again, the majority of participants really comprehend the SMarty mechanism to trace variabilities from a lower abstraction level diagram (sequence) to a higher level diagram (class) by means of the <<variability>> attribute `realizes+`.

Unfortunately, for the traceability analysis, we did not ask any open questions to participants to express their thoughts on it, because we did not want to extend the time for the participation in the experiment, thus causing more fatigue threats.

5 CONCLUSION

Regarding the first research question, the results on the effectiveness at configuring products showed an advantage of SMarty in relation to Ziadi et al. for both class and sequence diagrams.

We provide evidence the previous knowledge of the participant in SPL, variability and UML may be related to the effectiveness of Ziadi et al. to product configuration. Especially for SMarty, the knowledge seems not to determine such effectiveness, thus demanding less experienced participants.

With regard to the third research question, we understand SMarty provides subsidies for traceability of variability-related elements in both class and sequence diagrams. However, this aspect still needs to be improved. Ziadi, on the other hand, cannot be evaluated for not providing support for traceability of elements.

As future work we are developing an automated tool to UML-based approaches which takes as a basis any profile from the UML metamodel.

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