Development of New Metrics and their Empirical Evaluation to Assess Software Product Line Orthogonal Variability Model Maintainability

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Abstract- A software product line is a technique that represents the systems having conceptual similarity. All the systems that come in category of product line have commonalities and variability. A growing trend in software development is the requirement to develop new multiple and similar products at the same time instead of single individual product. There may be several reasons behind this. According to ISO the term quality can be defined as "the totality of characteristics of an entity that bear on its ability to satisfy stated or implied needs [1]. For continue the function of any product and evolve as needed, it is imperative to look upon all the quality attributes that may affect it in future. Quality attribute can be categorized into two types: internal and external. We can directly measure the internal quality attributes on the basis of product features such as size, length or complexity. Whereas the external attributes e.g. efficiency, reliability and maintainability can only be measure with respect to how software relates with its environment and therefore, can be measured once the software systems fully developed and deployed. One of these external quality attributes that is much valued at the present time is maintainability. Maintainability is according to ISO/IEC 9126 standard means "the capability of software product to be modified .In our research we develop new metrics and try to analyze these metrics for orthogonal variability models product line maintainability.

Keywords- Software Product Line, Orthogonal Variability Model, Quality attributes, Maintainability, Empirical evaluation.

I. INTRODUCTION

As defined by Clements, Software product line is "*A set of software intensive systems that share a common managed set of features satisfying the specific needs of a particular market segment"* [2]. Instead of developing an individual product, the growing trend in software engineering is to develop multiple product and similar products at one time. Software product line engineering (SPLE) provides a solution to eliminate this type of problem. Line means a set of products those are related and share commonalties like data structure, software components, some features and architecture etc. [3]. Software product line(SPL) is a set of software intensive systems that share a common, managed set of features to satisfy the specific needs of a particular market mission that are developed from common set of core assets in prescribed way[2].Software product line has two phases Domain engineering and Application engineering. In domain engineering, the common software artifacts are designed and developed for reuse. In application engineering, the specific products are derived by reusing a set of afore mentioned domain artifacts [4].With reference to the latest software quality model proposed by ISO(International Standard Organization) I.e. ISO/IEC 9126 model, Maintainability is the capability of software product to be modified. Maintainability is one of the external quality attributes. Others are Functionality, Efficiency, Portability, Reliability and Usability. All these characteristics have their own sub characteristics [1]. Maintainability is very important quality attribute and management of this quality attribute is still a problematic area. It has its own sub characteristics like analyzability, testability, changeability etc. Maintainability is concerned with evaluating how well the model is analyzable or changeable.The level of maintainability acts as a major determinant of the success or failure of the product line.

Although various attempts have been done in the domain of software measurement for improving product quality, but most of them practices the goal of evaluations in later stages by using quantitative measurements by nature. Measuring quality at early phase of development is the key area to develop high quality software product line.

In a nutshell, the major contributions of this paper are:

a) To describe the benefits of assessing maintainability quality attribute in reference to SPL orthogonal variability models.
b) Development of new metrics to assess SPL orthogonal variability models maintainability.
c) To empirically validate the developed metrics to assess OVM Maintainability.
d) To evaluate the level of correlation between metrics.

The remaining paper is organized as follows: Section II describe the OVM model.Quality and its different attributes are introduced in Section III; Section IV contains literature review over existing metrics. Section V describes design and experimental set up. Section VI explains analysis techniques and Section VII Results and Conclusion.

A. OVM

Orthogonal variability model is one of the best approaches for modeling the variability in software product line. OVM is a proposal for documenting software product line variability [5]. In OVM, only variability of product line can be documented. In this model VP (Variation Point) that documents a variable item and V(Variant) documents the possible instances of that variable item. All the variation points are related to at least one variant and each variant (V) is related tone VP. Both VPs and Vs. can be either mandatory or optional. A mandatory VP must always be bound i.e. all the products of the product line must have this VP and its Vs must always be chosen. An optional VP does not have to be bound, it may be chosen to specific products. Always that a VP, mandatory or optional, is bound, its mandatory Vs must be chosen to a specific product. Always that a VP, mandatory or optional is bound, its mandatory Vs must be chosen and is optional Vs can, but do not have to be chosen[6].

The following diagram shows the example of OVM Product line:

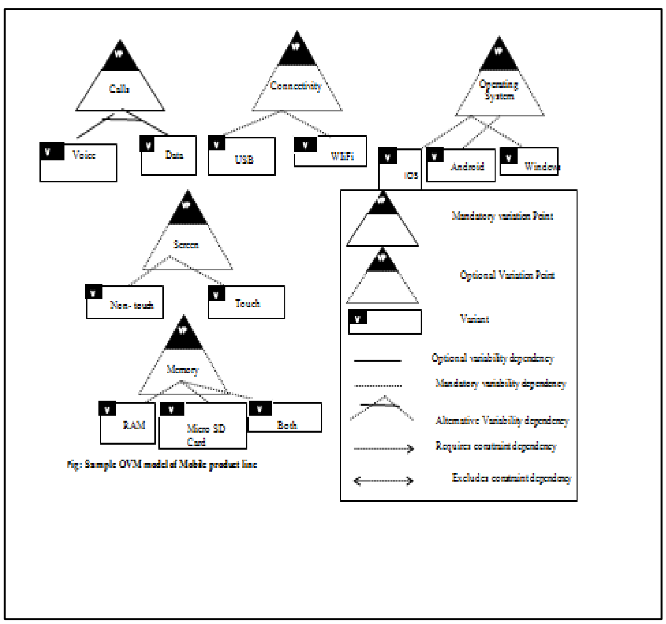

Fig: Sample OVM model of Mobile product line

B. QUALITY ATTRIBUTES

According to ISO the term quality can be defined as "the totality of characteristics of an entity that bear on its ability to satisfy stated or implied needs [1]. For continue the function of anyProduct and evolve as needed, it is imperative to look upon all the quality attributed that may affect it in future. Quality attribute can be categorized into two types: internal and external. We can directly measure the internal quality attributes on the basis of product features such as size, length or complexity. Whereas the external attributes e.g. efficiency, reliability and maintainability can only be measure with respect to how software relates with its environment and therefore, can be measured once the software systems fully developed and deployed. Since external quality attributes are difficult to evaluate in early phases of software development process. It is an indirect measurement based on internal quality attributes is devised. The reason being that internal quality attributes are suitable determinants for external quality attributes. One of these external quality attributes that is much valued at the present time is maintainability. Maintainability: Maintainability is according to ISO/IEC 9126 standard means "the capability of software product to be modified. Modification may include correctness, improvements or adaptation of the software to changes in environment, in requirements and functional specifications [1]. Maintainability is one of such external quality attributes is concerned with evaluating how well the developed software models can be understood changed and analyzed [8]. Research in the field of empirical software engineering has already shown that internal quality attributes can be appropriate determinants of external quality attributes [9,10].

Observing that the potential future significance of maintainability standards, it seems reasonable enough to study and analyze measures to assess maintainability quality attributes in reference to OVM product line. This assessment will lead to increased maintainability eventually leading to increase productivity, usage, adoption, satisfaction of user, and reduced development time and cost.

C. EXISTING STRUCTURAL METRICS

Metrics play an important role in improving software quality. We can use them to understand, control and improve development phase.It can be categorized as code and structured based. Structural metrics are those which can be used to assess the physical composition and configuration of the system. Literature review reveals that several metrics are proposed but limited to the domain of object oriented systems, UML diagrams, and program code[11][12][13][14][15][16].

The first approach towards the Metrics but it was used for feature models in the work of Bagehri et al. the author have proposed a set of metrics to measure structural complexity and size measure are as following:

a) Number of Features(NF)
b) No of Top Features(NTop)
c) Number of Leaf Feature(NLeaf)
d) Cyclomatic Complexity(CC)
e) Cross-Tree Constraints(CTC)
f) Coefficient of Connectivity Density(CoC)
g) Flexibility of Configuration(FoC)
h) No of Valid Configuration(NVC)
i) Depth of tree(DT)

In their experiment Bagehri et al[7] have proposed structural metrics to assess SPL feature models maintainability. It was not used for OVM product line models. Therefore, in our research we aim to develop new metrics which will be used for OVM product line models. Because we can use OVM model only on the base of variability. Also a research in this area is very important because most of the previous work has been done on the basis of feature models. And further experimentation will help in setting standards for assessment of quality attributes.

D. EXPERIMENT DESIGN AND SETUP

A) Goal of Study

First of all, the goal should be clearly defined foe conduction of successful experiment.In our experiment we have used standardized (GQM)Goal-question- Metric[18] template. The goal is shown in table 1.

TABLE1: GOAL OF THE EXPERIMENT THAT TO BE CONDUCTED

Analyze	**Structural complexity metrics for SPL OVM models**
For the purpose of	*Evaluating*
For the point of view	*Researchers*
In the context of	*MCA semester 5th and Mtech CSE semester 4th students*

E. VARIABLES

Independent Variables:

In our research we will develop our own independent variables. To which we categorize as independent because within the cause- effect relationship which is our major concern, they will represent the cause, i.e. we want to study if these metrics are or are not correlated with maintainability of software product line OVM.

Dependent Variables:

In our experiments the dependent variable will be maintainability of product line OVM**.**

F. OBJECTS OF STUDY

The models included in our experiment are changed from feature models. Some of feature models picked form Software Product Line Online Tools (SPLOT) and we changed then into OVM by own. Total 14 models were selected keeping in mind their understandability by the subjects of study. The language for the models is used English only.

G. DEVELOPMENT OF METRICS AND DATA COLLECTION

Till now we developed only six metrics these are:

1. No of total Variants (NoV)
2. No of Top Variants (NTopV)
3. No of Leaf Variants (NLeafV)
4. No of Variation Point (NVP)
5. No of Top Variation Point(NTopVP)
6. No of Leaf Variation Point(NLeafVP)

The aim of this study is to develop our own metrics and then recognize the relationship between developed metrics and with the subjective perception about the maintainability of OVM product line. All the developed metrics values obtained are tabulated in table 2.

TABLE2: METRICS VALUUES FOR ALL MODELS INCLUDED IN EXPERIMENT

OVM Model	NoV	NTopV	NLeafV	NVP	NTopVP	NLeafVP
Mobile	12	2	10	5	1	4
Hotel	13	4	9	6	2	4
Travel Agency	7	2	5	3	1	2
Washing Machine	7	2	5	3	1	2
Software	8	2	6	3	1	2
Edit text	11	4	7	3	1	2
Car	11	3	8	4	1	3
Banking	9	4	5	3	1	2
Laptop	12	4	8	3	1	2
Tablet	12	3	9	3	1	2
Games	11	4	7	4	1	3
Mobile media	13	3	10	4	1	3
Request management system	7	3	4	3	1	2
Weather forecasting	14	4	10	3	1	3

The subjective perception of the participants obtained through questionnaire. The process to gather the perception was as follows: the participants had taken in software engineering course; they were given a demo class. All the participants were kept unaware about hypothesis of the study. Time was given to them for communicate their queries about the models and their semantics.After this they were given the questionnaire to assess their subjective perception. In the questionnaire there were six sub questions (one for each sub characteristics) for all 14 models. The questionnaire queried the level of maintainability of the models on the basis of 7 point Likert scale[17] as shown in table 3.

TABLE 3: LINGUISTIC VALUES FOR SUBJECTIVE EVALUATION OF THE SUB CHARACTERSTICS OF MAINATINABILITY

Extremely Difficult	Very Difficult	A Bit Difficult	Neither Difficult Nor Easy	Quite Easy	Very Easy	Extremely Easy
1	2	3	4	5	6	7

Total 150 participants participated in experiment. The subjective perception of all the participants is shown in table 4. The values are based on the linguistic values that were shown in table 3.

TABLE 4: SUBJECTIVE OPINION OF THE PARTICIPANTS ABOUT ORTHOGONAL VARIABLITY MODEL MAINTAINABILITY

Orthogonal Variability Model	Analyzability	Changeability	Readability	Tailorabilty	Testability	Stability
Mobile	5	5	5	6	7	6
Hotel	7	5	5	5	5	5
Travel Agency	5	5	6	6	6	6
Washing Machine	6	5	6	6	6	5
Software	6	6	7	6	6	6
Edit text	5	5	5	5	7	5
Car	5	5	5	5	5	5
Banking	5	5	5	5	5	5
Laptop	5	6	6	5	6	6
Tablet	6	5	5	5	6	6
Games	6	6	6	5	6	6
Mobile application	5	5	6	6	6	6
Request Management System	6	6	5	5	6	6
Weather Station	6	6	6	5	5	5

H. VALIDATION OF DATA

Once we collected data, to ascertain the degree of consent among the subjects we employed the Cronbach'sAlpha[19]. This analysis is important as the subject should reach a certain level of agreement else convincing conclusions cannot be drawn. That's why we used Cronbach's Alpha to retrieve the level of resemblance among the qualitative behavior of the participants. Results are shown in table 5 obtained from test.

TABLE5: CRONBACH'S ALPHA FOR DEGREE OF RESEMBLANCE BETWEEN THE OPINIONS OF THE PARTICIPANTS

CRONBACH'S ALPHA						
No of Items	Analyzability	Changeability	Readability	Tailorability	Testability	Stability
14	.810	.822	.779	.780	.806	.789

As seen in above table that the degree of similarity of all the participants is above than 7. It indicates that there exists a reasonable agreement between participants. As a result this reliability analysis, we conclude that it is reliable for further analysis.

I. ANALYSIS TECHNIQUES

All the OVM model which we used in our experiment are from different domain and thus form satisfactory set of objects of study. They are also differs in metric values. The data collected empirically is also quantitatively reasonable. The quantity of data validates this. We have 12600 data points as participants' opinion (14 OVM models and 150 participants 6 sub characteristics). We applied these techniques for few prospective:

a) To study intra correlation of quality attributes
b) To study intra metrics correlation of designed metrics

II. RESULT AND ANALYSIS

A) INTRACORRELATION BETWEEN QUALITY ATTRIBUTES:

This results shows that which out of the subcharacteristics are correlated to each other. The results are shown in table

TABLE7: PEARSON CORRELATION FOR INTER QUALITY STUDY

		Level of Analyzability	Level of Changeability	Level of Readability	Level of Tailorability	Level of Testability	Level of Stability
Level of Analyzability	Pearson Correlation	1					
	Sig. (2-tailed)						
	N	14					
Level of Changeability	Pearson Correlation	.746**	1				
	Sig. (2-tailed)	.002					
	N	14	14				
Level of Readability	Pearson Correlation	.389	.529	1			
	Sig. (2-tailed)	.169	.052				
	N	14	14	14			
Level of Tailorabilty	Pearson Correlation	-.016	-.108	.513	1		
	Sig. (2-tailed)	.957	.712	.061			
	N	14	14	14	14		
Level of Testability	Pearson Correlation	.454	.241	.297	.578*	1	
	Sig. (2-tailed)	.103	.406	.303	.030		
	N	14	14	14	14	14	
Level of Stability	Pearson Correlation	.490	.420	.331	.344	.776**	1
	Sig. (2-tailed)	.076	.135	.247	.228	.001	
	N	14	14	14	14	14	14

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

B) INTRA CORRELATION OF METRICS WHICH WE DEVELOPED

Correlations

			NOV	NTopV	NLeafV	NVP	NTopVP	NLeafVP
Spearman's rho	**NOV**	**Correlation Coefficient**	1.000					
		Sig. (2-tailed)	.					
		N	14					
	NTopV	**Correlation Coefficient**	.478	1.000				
		Sig. (2-tailed)	.084	.				
		N	14	14				
	NLeafV	**Correlation Coefficient**	.938**	.185	1.000			
		Sig. (2-tailed)	.000	.526	.			
		N	14	14	14			
	NVP	**Correlation Coefficient**	.465	.044	.543*	1.000		
		Sig. (2-tailed)	.094	.881	.045	.		
		N	14	14	14	14		
	NTopVP	**Correlation Coefficient**	.349	.294	.209	.524	1.000	
		Sig. (2-tailed)	.221	.308	.473	.054	.	
		N	14	14	14	14	14	
	NLeafVP	**Correlation Coefficient**	.654*	.142	.713**	.904**	.464	1.000
		Sig. (2-tailed)	.011	.627	.004	.000	.095	.
		N	14	14	14	14	14	14

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

III. CONCLUSION AND FUTURE

In Software Product line it is very important to assess the quality of product line at the early phase that' why it is very important research area.In the end, we can say that we successfully we developed six metrics, by using of which we will furaccess the maintainability of orthogonal variability model product line. In future we will empirically in theoretically improve that the developed metrics can predict maintaianblity.

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