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Maintainability Measurement Model for Object-Oriented Design

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Abstract: Measuring maintainability near the beginning in the software development life cycle, particularly at design phase, may help the designers to integrate required improvement and corrections for improving maintainability of the developed software. This study developed a multivariate regression model 'Maintainability Estimation Model for Object-Oriented design' at Design phase in software development process. Developed model measures the maintainability of object oriented design in respect of Extendibility and Flexibility. Though, in order to quantify object oriented design's Extendibility and Flexibility the study required to develop two more models. These two models use design level object-oriented metrics, to quantify Extendibility and Flexibility of class diagram. Maintainability measurement in early stage of development cycle facilitates the designers to improve the maintainability of class diagram and consequently the maintainability of software. All the developed models have been empirically validated through proper statistical measures and contextual explanation has been drawn.

Keywords: Maintainability, Estimation, Metrics, Object Oriented Design.

I. INTRODUCTION

Software Engineering has turn into extremely essential discipline of study, practice and research. Everyone are working hard to decrease the problems and to meet the purpose of developing high-quality maintainable software that is delivered on time, within budget, and furthermore satisfies the requirements [1, 2]. Software has become significant to spreading out in almost all region of human endeavor. The skill of programming only is no longer enough to make large programs. There are serious problems in the price, time limit, post-maintenance and quality of software products [4]. Software engineering has the purpose of solving these problems by producing feature- quality maintainable software within time, financial plan. To attain this goal, we encompass to center in a closely controlled way on both, the quality of the software and on the process used to develop the software [5-7].

Maintainability has always been an elusive concept and its correct measurement or evaluation a difficult exercise. Most of the studies measure Maintainability or more precisely the attributes that have impact on Maintainability but at the source code level. Though, Maintainability measurement at the source code level is a good indicator of effort Measurement, it leads to the late arrival of information in the software development procedure [10, 12]. A choice to modify the design in order to improve Maintainability after coding has started may be very expensive and error-prone. While estimating Maintainability early in the development life cycle may really reduce the overall development cost. This chapter provides a roadmap to industry personnel and study to assess, and preferably, quantify software Maintainability in design phase [9]. A prescriptive framework has been proposed in order to integrate Maintainability within the development life cycle. It may be used to point of reference for software products according to their Maintainability.

II. MAINTAINABILITY FACTORS

Maintainability is a most important quality factor for delivering good quality software. Lack of maintainability donates to increased maintenance effort. The imminent provided by software maintainability is important for the level of software development life cycle, and quality assure. Design-for-maintainability is an extremely key issue in software engineering. An inferior grade of maintainability results means increased maintenance effort. An endeavor has been put forth to identify the major factors having direct impact on maintainability quantification at design time. Maintainability of an object oriented software design is affected by several factors, in which Extendibility and Flexibility is taken as a major factor. It has been concluded that Extendibility and Flexibility are the key factor affecting software maintainability [11].

III. DESIGN CHARACTERISTICS

Object oriented technology have turn into the most accepted and recognizable concept in software industry. Object oriented notion is now broadly used by software industry. Despite the truth that technology is not grown-up enough from testing point of view [13, 16, 18, 20], almost everybody speak about it, approximately everyone state to be doing it and nearly everyone says that it is superior than conventional function oriented design.

For the reason that most of the center of the object oriented approach to software development has been on analysis and design phase, only a small research studies have been faithful to explore the concept of maintainability in object oriented system.

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Object oriented ideology direct the designers what to carry and what to stay away from. Numerous measures have been defined so far to estimate object oriented design. There are various important themes of object orientation that are identified to be the foundation of internal quality of object oriented design and support in the perspective of measurement. These themes significantly take account of cohesion, coupling, inheritance, and encapsulation [22, 23].

IV. DATA COLLECTION

Data used during the study has taken from Genero et al. [3]. It contains Extendibility and Flexibility data, collected through a controlled experiment. This dataset has used in regression analysis for establishing the maintainability model taking Extendibility and Flexibility as independent, while maintainability as dependent variable. Another dataset has taken from Genero et al. [11]. It contains values of Extendibility, Flexibility and eleven metrics calculated from 28 class diagrams. The study has used this dataset for fitting two separate multivariate linear regression models for class diagram's Extendibility and Flexibility, taking class diagram's metrics as independent variables.

V. MODEL DEVELOPMENT

The generic quality model [4, 23] has been considered as a foundation to develop the Maintainability Measurements model for OOD. Measurement of class diagram's Extendibility and Flexibility is precondition for the accurate maintainability measurement model. Therefore before developing maintainability measurement model, the study has developed two models for Extendibility and Flexibility. In order to set up all the two models following multivariate linear model (1) has selected.

$$Y = \mu + \beta_1 * X_1 + \beta_2 * X_2 + \ldots\ldots + \beta_n * X_n + \varepsilon \quad (1)$$

Where
Y is dependent variables. X1 X2… Xn are independent variables. ß1, ß 2… ß n are the coefficients. € is error term and µ is the intercept

VI. FLEXIBILITY MEASUREMENT MODEL

In order to create a multivariate model for Flexibility of class diagram, metrics listed in [8], will play the role of independent variables whereas Flexibility will be in use as dependent variable.

The required data used for developing Flexibility measurement model is taken from [8]. The correlation in the middle of maintainability factors and object oriented characteristics has been established as depicted in equation2.

As per the mapping, Metrics 'DCC', 'CAM', 'MFA' are selected from [8] as independent variable to build up the Flexibility measurement mode[4]l. Using SPSS, values of coefficient are calculated and Flexibility model is formulated as given below:

Flexibility=3.878 + .153 × Coupling -2.664 × Cohesion + 9.211 × Inheritance (2)

Table1:Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients
		B	Std. Error	Beta
1	(Constant)	3.878	.755	
	Coupling	.153	.120	.204
	Cohesion	-2.664	.729	-.535
	Inheritance	9.211	1.764	.771

a. Dependent Variable: Flexibility

Table2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.982[a]	.965	.912	.37277

a. Predictors: (Constant), Inheritance, Cohesion, Coupling

Table3: ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.579	3	2.526	21.180	.053[a]
	Residual	.278	2	.139		
	Total	7.857	5			

a. Predictors: (Constant), Inheritance, Cohesion, Coupling

b. Dependent Variable: Flexibility

VII. EXTENDIBILITY MEASUREMENT MODEL

In order to create a multivariate model for Extendibility of class diagram, metrics listed in [8], will play the role of independent variables whereas Extendibility will be in use as dependent variable. The data used for developing Extendibility model is taken from [8]. The correlation in the middle of maintainability factors and object oriented characteristics has been established as depicted in equation

3. As per the mapping, Metrics 'DCC', 'CAM', 'NOP' are selected from [8] as independent variable to build up the Extendibility measurement model. Using SPSS, values of coefficient are calculated and Extendibility model is formulated as given below:

Extendibility =9.859 -11.186× Coupling +1.101× Cohesion + 3.102× Polymorphism (3)

Table4:Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients
		B	Std. Error	Beta
1	(Constant)	9.859	17.724	
	Coupling	-11.186	5.928	-.813
	cohesion	1.101	29.718	.017
	Polymorphism	3.102	2.104	.583

a. Dependent Variable: Extendibility

Table5:Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.896[a]	.803	.507	4.76608

a. Predictors: (Constant), Polymorphism, Coupling, cohesion

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Table6:ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	185.069	3	61.690	22.716	.281[a]
	Residual	45.431	2	22.716		
	Total	230.500	5			
a. Predictors: (Constant), Polymorphism, Coupling, cohesion						
b. Dependent Variable: Extendibility						

VIII. MAINTAINABILITY ESTIMATION MODEL

Before developing the model for maintainability, it is important to make sure the appropriate association among Maintainability, Flexibility and Extendibility of class diagrams. Table 7, shows the relationship values among them. From the correlation values it is clear that both Flexibility and Extendibility are strongly correlated with maintainability.

Table7: Correlations among Maintainability, Flexibility and Extendibility				
		Maintainability	Flexibility	Extendibility
Pearson Correlation	Maintainability	1.000	.895	.400
	Flexibility	.895	1.000	.757
	Extendibility	.400	.757	1.000

Maintainability=4.749 - .398 × Flexibility + .023 × Extendibility (4)

Table8 :Coefficients[a]				
Model		Unstandardized Coefficients		Standardized Coefficients
		B	Std. Error	Beta
1	(Constant)	4.749	.582	
	Flexibility	-.398	.058	-1.389
	Extendibility	.023	.007	.652
a. Dependent Variable: Maintainability				

Table9:Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.991[a]	.983	.948	.14140	.983	28.530	2	5	.131
a. Predictors: (Constant), Extendibility, Flexibility									

Table10 :ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.141	2	.570	28.530	.131[a]
	Residual	.020	5	.020		
	Total	1.161	3			
a. Predictors: (Constant), Extendibility, Flexibility						
b. Dependent Variable: Maintainability						

IX. EMPIRICAL VALIDATION

Empirical validation is a vital phase of proposed research. Empirical validation is the standard approach to justify the model approval. Taking view of this truth, practical validation of the maintainability model has been performed using sample tryouts. In order to validate developed maintainability model the data has been taken from [8].

Table11: Computed Ranking, Actual Ranking and their Relation					
Projects ↓	Maintainability Ranking		$\sum d^2$	r_s	$r_s \geq \pm .781$
	Computed Rank	Actual Rank			
P1	9	9	0	1.00	✓
P2	4	1	9	0.93	✓
P3	1	2	1	0.99	✓
P4	2	5	9	0.93	✓
P5	3	4	1	0.99	✓
P6	6	3	9	0.93	✓
P7	8	6	4	0.97	✓
P8	5	7	4	0.97	✓
P9	7	8	1	0.99	✓

Speraman's Coefficient of Correlation $\mathbf{r_s}$was used to check the significance of correlation among calculated values of maintainability using model and it's 'Known Values'. The 'r_s' was estimated using the method given as under: Speraman's Coefficient of Correlation

$$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)} \qquad -1.0 \leq r_s \leq +1.0$$

'd' = difference between 'Calculated ranking' and 'Known ranking' of maintainability.

n = number of projects used in the experiment.

The correlation values between maintainability through model and known ranking are shown in table ( ) above. Pairs of these values with correlation values $\mathbf{r_s}$above [±.781] are checked in table. The correlations are up to standard with high degree of confidence, i.e. up to 99%. Therefore we can conclude without any loss of generality that maintainability Estimation model measures are really reliable and significant and applicable.

X. CONCLUSION

The study has developed three models to compute Flexibility, Extendibility and maintainability of the class diagrams. Maintainability model measures the maintainability of object oriented design in terms of their Flexibility and Extendibility. All the models have been developed using the process of multiple linear regressions and validates the measuring ability of maintainability model. The practical validation on the maintainability measurement model shows that developed models are highly consistent, up to standard and significant. The values of Flexibility, Extendibility and maintainability are of instant use in the software development life cycle.

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