ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 3, March 2015

Reliability Estimation of Object-Oriented Software: Design Phase Perspective

Anil Kumar [1], Namrata Dhanda [2]

Scholar, Department of Computer Science, GITM, Lucknow, India[1]

Associate Professor, Department of Computer Science, GITM, Lucknow, India [2]

Abstract: This paper does a wide-ranging review on object oriented software Reliability, and put forth some appropriate information about design level Reliability. Reliability has been recognized as a major factor to software quality, an importance is being drawn to measure reliability early in development life cycle. In this study a metrics based Reliability Estimation Model for object oriented design has been developed. A suit of design metrics useful in measuring Reliability of software has been identified. Developed model measures the reliability of object oriented design in terms of 'Effectiveness' and 'Functionality. The study shows a relationship among 'design properties with reliability key factors Effectiveness and Functionality in accordance with its anticipated weight and significance. Finally the developed model has been empirically validated and contextual interpretation has been drawn using industrial software projects.

Keywords: Reliability, Estimation, Software Quality, Design Phase

I. INTRODUCTION

In today's world, the significance of producing quality oriented software is no longer a beneficial but a required factor. Regrettably, the majority of the software companies not only fails to deliver quality software to their customers, but in addition does not recognize the appropriate quality attributes [3]. The development of quality oriented software still leftovers a matter of proper guidelines, finest practices and undocumented expert knowledge. In the highly competitive software industry, customer pressure causes Companies to go faster the speed to deliver software products [4]. Though Schedules are frequently tightly limited; developers are required to weigh the importance of software quality against the possibility of missing deadlines. For meeting the objective, '*on time delivery'* testing time is normally reduced, which increases the prospective for defects, leading to problems with the final products.

This includes unfinished design, poor quality, high maintenance costs, and the risk of losing customer satisfaction. According to statistical information, more than 80% of all software delivered in the United States is not reviewed for defects, at a cost to the state economy of tens of billions of dollars each year [18]. Under these situations, software quality tends to suffer leading to severe consequences.

Software reliability is a key characteristic for software quality and is an essential factor to measure software failures [1]. Software Reliability is the property of referring 'how well software meets its specified requirements' and moreover 'the possibility of failure free operation for the particular period of time in a specified environment' [2].There are several mechanisms to makes the system more reliable [6]. Among several mechanisms object oriented design is one of the significant approach to measure reliability early in development life cycle. There is a common consensus among industry professionals and academicians in integrating Reliability within the development life cycle in order to deliver quality software. After the above conversation our conclusion is that Reliability is a quality factor [21].The goal of increasing the Reliability of software is not just to detect defects but more importantly, to detect defects as soon as they are initiated [22]. Therefore, reducing the price and overall time to fix the bug and producing higher quality reliable software each build of the release of development cycle.

II. RELIABILITY CRITERIA

Criteria are the characteristics which categorize the software quality factors. The criteria of the factors are the attributes of the software product by which the factor can be measured or characterized. Quality Criteria provide a more accurate and authentic definition of factors as well as common Criteria among factors facilitate to show the correlation among factors [12, 19]. Moreover design Criteria allow Estimation and review design metrics to be developed with greater acceptance and provide consent to recognize that area of software quality factors which may not be up to an acceptable standard [23]. After an exhaustive literature review it is appeared, Effectiveness and functionality are two of the most important reliability criteria [9].Its proper Estimation always support and help the designers to produce good quality reliable product within specified constraints.

III. RELIABILITY CRITERIA

Object oriented technology direct the designers and developers what to take and what to avoid from [20]. A Number of measures have been defined so far to assess

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 3, March 2015

object oriented design. There are a range of important themes of object oriented design that are recognized to be the basis of internal quality of object oriented software and help in the context of Estimation. These themes extensively take account of encapsulation, coupling, cohesion and inheritance [14, 16, 17].

Table1: OO Design Constructs Contributing in Reliability Estimation At Design Phase: A Critical Look

Design Parameters → / **Author/Study ↓**	**Cohesion**	**Coupling**	**Encapsulation**	**Inheritance**	**Abstraction**
MC Gregor et al. (1996)			√	√	
Bruce & Shi(1998)		√		√	
B.Pettichord(2002)		√			√
Baidry et al.(2002)		√			
M Bruntik (2004)			√	√	
S.Mouchawrab (2005)	√	√		√	√
I.Ahson et al.(2007)	√	√		√	
Nazir et al.(205)	√	√		√	
Abdullah et al.((2014)	√	√	√	√	
Khan et al. (2012)	√	√	√	√	
Nikfard &Babak(2013)		√	√	√	

IV. MODEL DEVELOPMENT

The generic quality model [11, 19] has been considered as a basis to develop the Reliability Estimation model for object oriented design.

Quantification of design diagram Effectiveness and Functionality is precondition for the Reliability Estimation Model. For that reason before developing reliability model, the research paper has developed 2 models for Effectiveness and Functionality. In order to develop all the models given below multivariate linear model has applied [11, 13].

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

V. EFFECTIVENESS ESTIMATION MODEL

Effectiveness is strongly related to reliability and regularly plays a key role to deliver high class, best quality reliable software within time and given budget [15]. It is one of the most important notions in design for testing of software programs and components [3]. In order to produce.

A multivariate model for Effectiveness of class diagram, metrics listed in [10], will play the responsibility of independent variables whereas Effectiveness will be in use as dependent variable. The required data used for developing Effectiveness Estimation model is taken from [10]. The correlation in the middle of reliability factors and object oriented characteristics has been established as depicted in equation 2.Using SPSS, values of coefficient are calculated and Effectiveness model is formulated as given below:

Effectiveness= - 4.559 + 2.557 × Encapsulation + .738 × Coupling + 5.353 × Inheritance (2)

Table2:Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-4.559	5.917		-.770	.522	-30.019	20.901
	Encapsulation	2.557	8.129	.082	.315	.783	-32.419	37.533
	Coupling	.738	.229	.876	3.225	.084	-.246	1.723
	Inheritance	5.353	2.442	.358	2.192	.160	-5.154	15.859

a. Dependent Variable: Effectiveness

Table 3: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	.977[a]	.954	.885	.81264	.954	33.835	3	2	.068

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

Table 4:ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	27.410	3	9.137	33.835	.068[a]
	Residual	1.321	2	.660		
	Total	28.731	5			

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

b. Dependent Variable: Effectiveness

VI. FUNCTIONALITY ESTIMATION MODEL

The responsibilities assigned to the classes of a design, which are made available by the classes through their public interfaces. This refers to a design's ability to achieve the desired functionality and behavior using object oriented design concept and techniques. In order to produce a multivariate model for functionality of class diagram, metrics listed in [10], will play the responsibility of independent variables whereas functionality will be in use as dependent variable. The required data used for developing functionality Estimation model is taken from [10]. The correlation in the middle of reliability factors and object oriented characteristics has been established as depicted in equation 3.Using SPSS, values of coefficient are calculated and Effectiveness model is formulated as given below:

Functionality = 1.656+ 1.141× Coupling + 13.336× Cohesion + -1.043× Inheritance (3)

Table 5:Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.656	3.752		.441	.702	-14.489	17.802
	Coupling	1.141	1.247	.472	.915	.457	-4.224	6.507
	Cohesion	13.336	6.694	1.095	1.992	.185	-15.466	42.137
	Inheritance	-1.043	.751	-.701	-1.388	.300	-4.276	2.190

a. Dependent Variable: Functionality

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 3, March 2015

Table 6: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	.824[a]	.680	.199	1.12609	.680	31.414	3	2	.440
a. Predictors: (Constant), Inheritance, Coupling, Cohesion									

Reliability= 1.384 -.284 × Effectiveness -.096 × Functionality (4)

Table 7:ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.379	3	1.793	31.414	.440[a]
	Residual	2.536	2	1.268		
	Total	7.915	5			
a. Predictors: (Constant), Inheritance, Coupling, Cohesion						
b. Dependent Variable: Functionality						

VII. RELIABILITY MODEL

Before developing the model for Reliability, it is important to make sure the appropriate association among Reliability, Effectiveness and Functionality of class diagrams. Table 8, shows the relationship values among them. From the correlation values it is clear that both Effectiveness and Functionality are strongly correlated with Reliability [10].

Table 8:Correlations				
		Reliability	Effectiveness	Functionality
Pearson Correlation	Reliability	1.000	.439	.721
	Effectiveness	.439	1.000	.917
	Functionality	.721	.917	1.000

Table 9:Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.384	.491		2.822	.106	-.727	3.496
	Effectiveness	-.284	.148	-1.401	-1.917	.195	-.922	.354
	Functionality	-.096	.035	-2.006	-2.744	.111	-.246	.054
a. Dependent Variable: Reliability								

Table 10: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	.911[a]	.831	.661	.22637	.831	24.901	2	2	.169
a. Predictors: (Constant), Functionality, Effectiveness									

Table 11:ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.502	2	.251	24.901	.169[a]
	Residual	.102	2	.051		
	Total	.605	4			
a. Predictors: (Constant), Functionality, Effectiveness						
b. Dependent Variable: Reliability						

VIII. EMPIRICAL VALIDATION

Empirical Validation is an essential part of proposed research. Empirical Validation is the standard approach to give good reason for the model approval. Taking view of this reality, practical validation fo the reliability model has been performed using sample tryouts. In order to validate developed reliability model the data has been taken from[19]

Table11: Computed Ranking, Actual Ranking and their Relation					
Projects ↓	Reliability Ranking		$\sum d^2$	r_s	$r_s > \pm.781$
	Computed Rank	Actual Rank			
P1	5	2	9	0.945455	✓
P2	7	5	4	0.975758	✓
P3	3	1	4	0.975758	✓
P4	8	6	4	0.975758	✓
P5	9	9	0	1.000000	✓
P6	4	3	1	0.993939	✓
P7	6	7	1	0.993939	✓
P8	2	4	4	0.975758	✓
P9	1	8	49	0.70303	×
P10	10	10	0	1.00000	✓

Speraman's Coefficient of Correlation r_s was used to verify the importance of correlation among calculated values of reliability using model and it's 'Known Values'. The 'r_s' was estimated using the technique given as under:
Speraman's Coefficient of Correlation

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

'd' = difference between 'Calculated ranking' and 'Known ranking' of reliability.
n = number of projects (n=10) used in the experiment.

The correlation values amid reliability through model and known rating are shown in table (11) above. Pairs of these values with correlation values r_s above [±.781] are checked in table. The correlations are up to standard by high degree of confidence, i.e. up to 99%. Therefore we can conclude without any loss of generality that reliability Estimation model measures are really reliable and considerable and relevant.

IX. CONCLUSION

The research study has developed three models namely Effectiveness Estimation Model, Functionality Estimation Model and finally Reliability Estimation Model for object oriented design. , Reliability Estimation Model measures the, Reliability of design class diagrams in respect of their Effectiveness and Functionality. The paper additionally validates the quantifying ability of Reliability Estimation Model. Beside these, a reliability index can also be developed that may help other researchers in measuring reliability of object oriented design.

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 3, March 2015

REFERENCES

[1] Zainab Al-Rahamneh, Mohammad Reyalat, Alaa F. Sheta, Sulieman Bani-Ahmad, Saleh Al-Oqeili,, "A New Software Reliability Growth Model: Genetic-Programming-Based Approach", Journal of Software Engineering and Applications, 2011, Vol: 4, PP:476-481 doi:10.4236/jsea.2011.48054..

[2] Natasha Sharygina , James C. Browne, and Robert P. Kurshan, "A Formal Object-Oriented Analysis for Software Reliability: Design for Verification", 2011, pp:1-15

[3] Abdullah, Dr, Reena Srivastava, and M. H. Khan."Modifiability: A Key Factor To Testability", International Journal of Advanced Information Science and Technology, Vol. 26, No.26, Pages 62-71 June 2014.

[4] Nikolaos Tsantalis, Alexander Chatzigeorgiou, "Predicting the Probability of Change in Object-Oriented Systems", IEEE Transactions on Software Engineering, VOL. 31, NO. 7, July 2005, pp: 601-614.

[5] Stephanie Gaudan , Gilles Motet and Guillaume Auriol , "A new structural complexity metrics applied to Object Oriented design reliability assessment", http://www.lesia.insa-toulouse.fr/~motet/papers/2007_ISSRE_GMA.pdf.

[6] Mahfuzul Huda, Dr.Y.D.S.Arya, and Dr.M. H. Khan. "Measuring Testability of Object Oriented Design: A Systematic Review." International Journal of Scientific Engineering and Technology, Vol. 3, Issue 10, pp: 1313-1319 Oct, 2014.

[7] Everald E. Mills, "Software Metrics", SEI Curriculum Module SEI-CM-12-1.1, Software Engineering Institute, Dec 1988, pp: 1-43.

[8] Haifeng Li Minyan Lu Qiuying Li , "Software Reliability Metrics Selecting Method Based on Analytic Hierarchy Process", Sixth International Conference on Quality Software, 2006. QSIC 2006, 27-28 Oct. 2006, pp: 337 – 346, ISSN: 1550-6002, ISBN: 0-7695-2718-3.

[9] Offutt, J. and R. Alexander, (2001): A fault Model for Subtype Inheritance and Polymorphism. In 12th International Symposium, Software Reliability Engineering, Nov 27-30, 2001, IEEE, pp. 84-93.

[10] Jagdish Bansiya, "A Hierarchical Model for Object Oriented Design Quality Assessment", IEEE Transaction of Software Engineering, Volume 28, No. 1, January 2002, and pp: 4-17

[11] Abdullah, Dr, M. H. Khan, and Reena Srivastava. "Testability Estimation Model for Object Oriented Design (TMM^{OOD})." International Journal of Computer Science & Information Technology (IJCSIT) Vol. 7, No 1, February 2015, DOI: 10.5121/ijcsit.2015.7115.

[12] F. Li., T.Yi, "Apply Page Rank Algorithm to Measuring Relationship's Complexity", IEEE, DOI 10.1109/ PACIIA.2008.309, pp. 914-917, 2008, ISBN: 9780769534909.

[13] Abdullah, Dr, Reena Srivastava, and M. H. Khan. "Testability Estimation Framework: Design Phase Perspective."International Journal of Advanced Research in Computer and Communication Engineering Vol. 3, Issue 11, Pages 8573-8576 November 2014.

[14] Yong Cao Qingxin Zhu. Improved metrics for encapsulation based on information hiding. DOI: 10.1109/ICYCS.2008.76, The 9th International Conference for Young Computer Scientists, IEEE computer society 2008, p: 742-724.

[15] Mahfuzul Huda, Dr.Y.D.S.Arya, and Dr. M. H. Khan. "Evaluating Effectiveness Factor of Object Oriented Design: A Testability Perspective." International Journal of Software Engineering & Applications (IJSEA), Vol.6, No.1, January 2015, DOI:10.5121/ijsea.2015.6104.

[16] Sch aril N., Black Andrew P., Ducasse S. Object oriented Encapsulation for Dynamically Typed Languages. OOPSLA 2004, ACM, pp: 130–139.

[17] Abdullah, Dr, Reena Srivastava, and M. H. Khan. "Testability Estimation of Object Oriented Design: A Revisit". International Journal of Advanced Research in Computer and Communication Engineering Vol. 2, Issue 8, pages 3086-3090, August 2013.

[18] Usha Chhillar, Shuchita Bhasin , " A New Weighted Composite Complexity Measure for Object-Oriented Systems", International Journal of Information and Communication Technology Research Volume 1 No. 3, July 2011,pp: 101-108, ISSN-2223-4985.

[19] Dromey, R.G.: A Model for Software Product Quality. IEEE Transaction on Software Engineering 21(2), 146–162 (1995).

[20] Abdullah, Dr, M. H. Khan, and Reena Srivastava. "Flexibility: A Key Factor To Testability", International Journal of Software Engineering & Applications (IJSEA), Vol.6, No.1, January 2015. DOI: 10.5121/ijsea.2015.6108.

[21] Fiondella, L.; Gokhale, S.S., "Software reliability model with bathtub-shaped fault detection rate" Reliability and Maintainability Symposium (RAMS), 2011 Proceedings - Annual , 24-27 Jan. 2011,pp: 1 – 6, ISBN: 978-1-4244-8857-5.

[22] Mahfuzul Huda, Dr.Y.D.S.Arya, and Dr. M. H. Khan. "Testability Quantification Framework of Object Oriented Software: A New Perspective." International Journal of Advanced Research in Computer and Communication Engineering, Vol. 4, Issue 1, Jan, 2015, DOI: 10.17148/IJARCCE.2015.4168.

[23] Mohan, K.K.; Verma, A.K.; Srividya, A., "Software reliability estimation through black box and white box testing at prototype level ", 2nd International Conference on Reliability, Safety and Hazard (ICRESH), 14-16 Dec. 2010, pp: 517 - 522, ISBN: 978-1-4244-8344-0.