ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 5, May 2015

Testability Estimation Of Object Oriented Design: A New Perspective

Rishabh Srivastava[1], Namrata Dandha[2], Siddhartha Lavaniya[3]

Research Scholar, CS, GITM, Lucknow, India [1]

Associate Professor&Head CS&IT, CS&IT, GITM, Lucknow, India [2]

Assistant Professor, CS, GITM, Lucknow, India[3]

Abstract: Estimating testability near the beginning in the software development process particularly at design stage is a criterion of key importance for software developers, designers, practitioners and quality controllers. As a matter of fact, researchers and practitioners highly advocated the need of an accurate and efficient measurement of software testability at design phase in development life cycle. There is a common understanding between academicians and industry professionals in incorporating testability in development life cycle in order to produce quality software. Unluckily, there is no standard guideline or methodology available to compute software testability. An endeavor has been put forth in this research paper to identify the testability key factors supporting in testability measurement especially at design phase of development life cycle. Study has identified the 'Understandability' and 'Modifiability' is the two major factors for measuring testability in design phase. Taking into account of their contribution in testability measurement a model has been developed to quantify object oriented design testability. After that the developed model has been validated with the help of experimental test and justified by statistical measures.

Keywords: Software Testing, Testability, Quality, Object Oriented Characteristics, Testability Factors.

I. INTRODUCTION

This Testing is a major cost driven activity for development and testing of object oriented software. The entire effort spent on software testing not only depends on process, issues human factors, test tools and test techniques, but also on properties of the object oriented development artifacts. The point to which a software artifacts support test tasks in a given testing context is called software testability [1, 2]. If we want to improve testability of software we have to recognize those components of a program that lack testability of software. This can be done by reviewing object oriented artifacts and with help of appropriate metrics based on design guideline and source code level. In this work we focus on testability measurement for object oriented design taking into consideration 'Understandability' and 'Modifiability' as testability major factors.

Testability is one of the significant quality indicators since its measurement leads to the prospect of facilitating and improving a test process. The process of software engineering creates a unique problem for testability [3,4]. Testability study has been an important research area since 1991s and becomes more pervasive when entering 21st century [5]. Testability, comprising of certain characteristics of a software sys-tem that makes it easier or harder to test and to analyze the test results, is a vital factor to get an effective and efficient test process. Designing, verifying and measuring highly testable software becomes an important and challenging task for software developers. Improving software testability is clearly an important goal in order to diminish the number of defects that result from poorly designed software [6,7].

Testable design is more specific then good design because it is explicitly intended to match a particular test context. One pro-active strategy that organizations can adopt is to design their software products with testability as one of the key design criteria. Aspects of testability like Observability and reproducible behavior are not the primary focus of good design and re-quire special treatment. A design is a process that starts from a study of a domain problem leading to some formal documentation. Software design, in some ways, is a strange art [7].

II. TESTABILITY

Software Testability is one of the most essential quality parameters and its early measurement facilitating and improving test process. The approaching provided by testability is valuable during software design, implementing, testing and in quality assurance [8,9,10]. The characteristics of testable

Software like adequate complexity, low coupling and good separation of concerns make it easier for reviewers to understand the software artifacts under review [11].Testability results from good Software Engineering practice and an effective software process. Although, testability is most obviously relevant during testing, but paying attention to testability early in the development process, testing efficiency and effectiveness may potentially be improved. Testability can be perceived as the property and/or characteristic that estimates the ease of functionality or testing a component of code and a provision included in software so that test scripts and plans can be executed analytically. Testability analysis can add information that is useful both for assessing the overall

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 5, May 2015

quality and for locating software bugs [12]. Hence, it provides a trade-off analysis tool for designers to help them in deciding whether they are willing to pay the penalty for testability at the cost of other benefits. Testability is software quality characteristics whose major part is concerned with defect identification and removal for improved testability and test cost control [13].

III. IDENTIFICATION OF OBJECT ORIENTED DESIGN METRICS & DATA COLLECTION

Researchers have proposed several object oriented metrics in past decades for qualitative assessment of object oriented design [14, 15, 16]. These metrics are valid and widespread accepted by a large community of researchers and developers due to its accuracy. After a regress review of these accepted metrics some of existing metrics which are well suited for object oriented designing & required dataset has been taken from Genero [17].These metrics are helpful for qualitative and quantitative assessment of understandability of software design for improved results for testability.

IV. ESTABLISHING CORRELATION

The contextual impact relationship between understandability and object oriented design constructs has been established. The values of these software metrics can be identified with the help of class diagram. The quantifiable assessment of understandability is very supportive to get testability value of object oriented design for low cost maintenance.

In order to create a model for understandability, multiple linear regression methods have been used. The proposed linear model is as follows:

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

Where Y is dependent variable and X1, X2…….Xn are independent variables.

ß1, ß 2…… ß n are the coefficient of the independent variables.

The data is taken for understandability model from [17] that is a controlled experiment of diagrams. As per Equation (1) understandability is taken as independent variable. Using these data, the coefficient calculated for inheritance, coupling and cohesion to show the relationship with design properties. Equation 2 summarizes the computational formula for understandability with the component weightage.

V. DEVELOPING MODEL FOR UNDERSTANDABILITY

In order to develop an Understandability model of object oriented design, metrics listed in [18, 19, 21, 22] play the job of independent variables at the same time as Understandability will be as dependent variable. The data used for developing Understandability model is taken from [20]. Using SPSS, values of coefficient are calculated and Understandability model is created as below.

Understandability=1.900 + 2.800 × Coupling -.300 × cohesion -1.300 × Inheritance (2)

Table 1. Coefficients[a]

Model		Unstandardized Coefficients		Standardized	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.900	1.572		1.209	.350
	Coupling	2.800	1.442	1.740	1.941	.192
	cohesion	-.300	.173	-1.257	-1.732	.225
	Inheritance	-1.300	1.852	-.438	-.702	.555

a. Dependent Variable: Understandability

Table 2. 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	.820[a]	.673	.182	1.09545	.673	1.370	3	2	.448

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

Table 3. ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.933	3	1.644	1.370	.448[a]
	Residual	2.400	2	1.200		
	Total	7.333	5			

a. Predictors: (Constant), Inheritance, cohesion, Couping

Table 3. ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.933	3	1.644	1.370	.448[a]
	Residual	2.400	2	1.200		
	Total	7.333	5			
a. Predictors: (Constant), Inheritance, cohesion, Couping						
b. Dependent Variable: Understandability						

VI. DEVELOPING MODEL FOR MODIFIABILITY

In order to develop a Modifiability model of object oriented design, metrics listed in [20] play the job of independent variables at the same time as Modifiability will be as dependent variable. The data used for developing Modifiability model is taken from [20]. Using SPSS, values of coefficient are calculated and Modifiability model is created as below.

Modifiability = .305+ .093× encapsulation + .240× coupling +.932× cohesion+ .291×Inheritance (3)

Table 4. Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.305	1.148		.266	.835
	NM	.093	.098	1.577	.948	.517
	NAssoc	.240	.210	.436	1.141	.458
	NAgg	.932	1.474	-1.205	-.632	.641
	MaxDIT	.291	.992	.223	.294	.818
a. Dependent Variable: Modifiability						

VII. STATISTICAL SIGNIFICANCE OF MODEL

The coefficient table (2) presents the statistical significance of independent variables. A linear regression relationship has been established between dependent variable and independent variables to check whether it is statistically significant or not. The coefficient table 2 and summary table 3 describes that the metrics are statistically significant at a significant level of 0.05(equivalent to a confidence level of 95%).

Table 5. Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.997[a]	.993	.965	.46284	.993	35.734	4	1	.125
a. Predictors: (Constant), MaxDIT, NAssoc, NM, NAgg									

Table 6. ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	30.619	4	7.655	35.734	.125[a]

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 5, May 2015

	Residual	.214	1	.214		
	Total	30.833	5			
a. Predictors: (Constant), MaxDIT, NAssoc, NM, NAgg						
b. Dependent Variable: Modifiability						

VIII. TESTABILITY MODEL

The generic quality models [15, 20] have been taken as a base to develop the Testability Model for Object Oriented Design. In order to set up a model for Testability estimation, a multiple linear regression method has been used to get the coefficients. Applying this method, Understandability Model (2), Modifiability Model (3) have been developed respectively.

Testability= -25.814+ 9.400× Understandability + 122.778× Modifiability (4)

Table 7. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-25.814	134.625		-.192	.866
	Understandability	9.400	8.024	.406	1.171	.362
	Modifiability	122.778	58.890	.722	2.085	.172
a. Dependent Variable: Testability						

Table 8. 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	.874[a]	.765	.529	46.13284	.765	3.250	2	2	.235
a. Predictors: (Constant), Modifiability, Understandability									

In addition the consideration of R2 (Coefficient of Determination) and adjusted R2 in the Table above, is too very positive. As, it refers to the percentage of the whole variance in testability by all the two factors (independent variables) participating in the model (4).

Table 9. ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13832.048	2	6916.024	3.250	.235[a]
	Residual	4256.477	2	2128.239		
	Total	18088.525	4			
a. Predictors: (Constant), Modifiability, Understandability						
b. Dependent Variable: Testability						

IX. EMPIRICAL VALIDATION OF DEVELOPED MODEL

Empirical validation is an important step of proposed research work. Empirical validation is the standard approach to justify the developed model approval.

Practical validation of the model has been performed using sample tests. In order to validate developed Testability estimation model the data has been taken from [19].

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 5, May 2015

Table10: Computed Ranking, Actual Ranking and their Relation

Projects ↓	Testability Ranking		$\sum d^2$	r_s	$r_s > \pm.781$
	Computed Rank				
P1	1	5	16	0.90	✓
P2	2	3	1	0.99	✓
P3	4	2	4	0.98	✓
P4	3	8	25	0.85	✓
P5	6	1	25	0.85	✓
P6	5	6	1	0.99	✓
P7	9	9	0	1.00	✓
P8	8	10	4	0.98	✓
P9	7	4	9	0.95	✓
P10	10	7	9	0.95	✓

- **r_s above±.781** means significant results.

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

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

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

n = number of projects (n=10) used in the experiment.

The correlation values between testability through calculated rank and known ranking are shown in table ( ) . Pairs of these values with correlation values r_s above [±.781] are checked in critical table. The correlations are standard with high degree of confidence, i.e. up to 99%. Therefore we can conclude without any loss of generality that testability Estimation model is reliable and significant.

X. Conclusion

Software testability is very important and one of the most considerable quality criteria of the software development process. The lack of testability aspect often leads to false analysis that may in turn lead to misunderstanding and hence to faulty development products. Form the correlation values it is clear that both Understandability and Modifiability are strongly correlated with testability. It plays a significant role as far as the issues of delivering quality software are concerned. Therefore the testability model has been validated empirically using experimental tryout. Outcome shows that the value of testability computed through model are highly correlated with the 'known values'. The applied validation on the testability estimation model concludes that developed model is highly consistent, acceptable and reliable.

References

[1] Gao, J., Shih, M.-C.: A Component Testability Model for Verification and Measurement. In: Proc. of the 29th Annual International Computer Software and Applications Conference, pp. 211–218. IEEE Comp. Society (2005)

[2] IEEE Press, "IEEE Standard Glossary of Software Engineering Technology,"ANSI/IEEE Standard 610.12-1990, 1990.

[3] ISO, "International standard ISO/IEC 9126. Information technology: Software product evaluation: Quality characteristics and guidelines for their use." 1991.

[4] 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.

[5] Zhao, L.: A New Approach for Software Testability Analysis. In: Proceeding of the 28th International Conference on Software Engineering, Shanghai, pp. 985–988 (2006)

[6] Huda, M., Arya, Y.D.S. and Khan, M.H. (2014) Measuring Testability of Object Oriented Design: A Systematic Review. *International Journal of Scientific Engineering and Technology* (*IJSET*), **3**, 1313-1319.

[7] Bruntink, M. and Van Deursen, A. (2004) Predicting Class Testability Using Object-Oriented Metrics. *Proceedings of the Fourth IEEE International Workshop on Source Code Analysis and Manipulation*, Chicago, 15-16 September 2004,136-145.

[8] Amin, A. and Moradi, S. (2013) A Hybrid Evaluation Framework of CMM and COBIT for Improving the Software Development Quality.

[9] Zheng, W.Q. and Bundell, G. (2008) Contract-Based Software Component Testing with UML Models. *International Symposium on Computer Science and Its Applications* (*CSA* '08), 978-0-7695, 13-15 October 2008, 83-102.

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

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

[12] Huda, M., Arya, Y.D.S. and Khan, M.H. (2015) Quantifying Reusability of Object Oriented Design: A Testability Perspective. *Journal of Software Engineering and Applications*, **8**, 175-183. http://dx.doi.org/10.4236/jsea.2015.84018

[13] 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.

[14] Bansiya, Jagdish, and Carl G. Davis. "A hierarchical model for object-oriented design quality assessment." Software Engineering, IEEE Transactions on 28.1 (2002): 4-17.

[15] Abdullah, Dr, M. H. Khan, and Reena Srivastava. "Testability Measurement 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.

[16] Huda, M., Arya, Y.D.S. and Khan, M.H. (2015) Testability Quantification Framework of Object Oriented Software: A New

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 5, May 2015

Perspective. *International Journal of Advanced Research in Computer and Communication Engineering*, **4,298**-302. http://dx.doi.org/10.17148/IJARCCE.2015.4168

[17] M. Genero, J. Olivas, M. Piattini, and F. Romero, "A Controlled Experiment for Corroborating the Usefulness of Class Diagram Metrics at the Early Phases of Object-Oriented Developments," *Proc. of the ADIS 2001, Workshop on Decision Support in Software Engineering*, vol. 84. Spain, 2001

[18] Fu, J.P. and Lu, M.Y. (2009) Request-Oriented Method of Software Testability Measurement. *Proceedings of the ITCS* 2009 *International Conference on Information Technology and Computer Science*, Kiev, 25-26 July 2009, 77-80.

[19] Huda, M., Arya, Y.D.S. and Khan, M.H. (2015) Evaluating Effectiveness Factor of Object Oriented Design: A Testability Perspective. *International Journal of Software Engineering & Applications*(*IJSEA*),**6,4149**. http://dx.doi.org/10.5121/ijsea.2015.6104

[20] Lee, Ming-Chang. "Software Quality Factors and Software Quality Metrics to Enhance Software Quality Assurance." British Journal of Applied Science & Technology 4.21 (2014).

[21] Huda, M., Arya, Y.D.S. and Khan, M.H. (2015) Metric Based Testability Estimation Model for Object Oriented Design: Quality Perspective. *Journal of Software Engineering and Applications*, **8**, 234-243. http://dx.doi.org/10.4236/jsea.2015.84024

[22] Badri, M. and Toure, F. (2012) Empirical Analysis of Object-Oriented Design Metrics for Predicting Unit Testing Effort of Classes. *Journal of Software Engineering and Applications*, **5**, 513-526.http://dx.doi.org/10.4236/jsea.2012.57060

[23] 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.

[24] Mouchawrab, S., Briand, L.C. and Labiche, Y. (2005) A Measurement Framework for Object-Oriented Software Testability. *Information and Software Technology*, **47**, 979-997. http://dx.doi.org/10.1016/j.infsof.2005.09.003

[25] Jungmayr, S. (2002) Testability during Design, Softwaretechnik-Trends. *Proceedings of the GI Working Group Test, Analysis and Verification of Software*, Potsdam, 20-21 June 2002, 10-11.