A COMPREHENSIVE INTERPRETATION OF OBJECT ORIENTED METRICS FOR QUALITY REFINEMENT IN SOFTWARE DEVELOPMENT

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Abstract: In Digital era, Software in electronic devices has become an indispensable to our daily life. Software Metric is a significant software engineering field that plays a quality role in software measurement. Better measurement and metrics are stepping stone to software growth with distinction. Moving from measurement to metrics is like moving from observation to understanding. Metrics are conceived by the user and designed to reveal a chosen characteristic in a reliable and meaningful manner. Object Oriented Software is based on approach that works around the real-world entities and their characteristics. Object Oriented Software measurement is procedure in which calculations are done on real world entities to describe them according to clearly defined rules. Object Oriented Metric plays a vital role to find the efficiency of the software and improvement for future. The measurement of object oriented software seems to be a powerful tool for product effectiveness. This paper will analyze different Object Oriented Metrics and helpful for ensuring quality design with high cohesion and low coupling for advancement in Object Oriented Software Development.

Keywords: Software Measurement; Object Oriented Metrics; Analysis; Design; Quality Factors

I. INTRODUCTION

Software Development is a salient phase in software life cycle that is to be created as per user specification requirements and it can be assessed for well-engineered quality product against predefined criteria [1]. Software Design is a backbone of four major areas of concern - data, architecture, interfaces and components [2]. Software design and development process is very necessary step of software development life cycle. The emphasis in design is on quality and this phase provides depiction of software that can be assessed for well-engineered quality [3].

Software Quality is a mechanism that evaluates, assesses, and improves the accomplishment of software. Software quality is elucidating as the degree to which software meets requirements for reliability, maintainability, portability as contrasted with functional, performance, and interface requirements that are satisfied as a result of software engineering [4,10]. In the past decade, many IT companies have started to deploy object oriented technology in their software development efforts. Object Oriented Software Development is concept of the real-world entities and their features creation instead of functions involved in the software. Objects have their own internal data structure which defines their data and functions. Object Oriented Design restrained all the properties and worth of software that is allied to any large or small project.

Software Metric is a measurement term of a degree to which a software system holds some characteristics. These metrics are based on actual project experiences; these are not law of nature. These are guidelines that give indication of the progress that a project has made and the quality of the design [5]. Moving from measurement to metrics is like moving from observation to understanding. Metrics are conceived by the user and designed to reveal a chosen characteristic in a reliable and meaningful manner [6]. Object Oriented Metrics concentrate on measurement that can be applied to the class and the design characteristics as Localization, Encapsulation, Inheritance, Information hiding, Polymorphism, Messaging and Object abstraction [7]. There is exigency for Object Oriented Metrics due to visibility, planning and control, quality, productivity [8]. Software quality and reliability describes as fault-free software operation for a specified period of time [9].

Fig. 1 – Significance of Metrics [6]

Software Metric recommends for project managers to find proficiency of the software. This is done by collecting quality, productivity and effectiveness of data and then analyzing and comparing these data with past averages in order to find whether quality improvements have occurred [10]. Different Object Oriented metrics have been proposed by various researchers and Metric Quality Design suggested in this work based on object oriented metric interpretation to deliver quality product.
II. LITERATURE REVIEW

Lorenz, M., et al. explored metrics based on static snapshots of the system at a point in time. None of them are currently based on the runtime execution of the system. Any explicit or implied use of the word dynamic refers to the changes in the state of project measurements over multiple static snapshots. These metrics should be used to support the desired motivation [5].

Chidamber, S.R., et al. proposed six object-oriented software metrics and these are the intellectual research for object-oriented software development. These metrics are utilized with a theoretical idea in measurement of objects, and which incorporate the experiences for software managers and evaluation done by these metrics against criteria for credibility and existing empirical data from commercial software to explain the features of metrics on real-world applications and recommends the process in which these metrics may be utilized [11].

Xenos, M., et al. explained the outcome derived from survey on software metrics used in object-oriented environments and covers a small set of the most known and commonly used traditional software metrics which could be applied to object-oriented programming and collection of metrics. These metrics interpreted with present meta metrics based on the interpreter’s point of view, and used implementation in three languages as Object Pascal, C++ and Java [12].

Aggarwal, K.K., et al. conducted an analysis of 22 metrics given by different researchers and utilized these metrics on software for empirical study. The metrics are first defined and then explained using practical applications. They have applied on standard projects on the basis of which descriptive statistics, principal component analysis and correlation analysis was done [13].

Rao, N.S. in thesis, a set of object-oriented reuse metrics have been proposed at class level namely Method Reuse Factor, Attribute Reuse Factor, Method Reuse Factor with Inheritance and Attribute Reuse Factor with Inheritance. This research work explored on process and product to improve the process level measurement, Object Oriented DFP has been chosen and the attribute reuse factor with inheritance has been applied on the OODFP and it has been proved by incorporating [14].

Kayarvizhy, N., et al. explored on the design of an automated object-oriented software metric tool which has a generic framework for computing the metrics automatically. This software tool converts the source code developed using a particular object-oriented programming to a language independent XML format which is then used for computing the needed software metrics [15].

Dubey, S.K., et al. interpreted object-oriented software metrics ensuring to minimize maintenance cost effort to estimate software failures and errors. They reviewed object-oriented software metrics and analysis table is explored by which evaluation of the comparison between all various software metrics done efficiently [16].

Gulia, P. in thesis, contributes to a better understanding of object-oriented system, its measurement and testing. Firstly, the proposed work provides a theoretical framework to the measurement and testing of object-oriented system. This framework is helpful for designing appropriate research studies to know the objectives and make decisions on the basis of these objectives [17].

Huang, R., et al. research seeks to describe concepts and techniques to improve the quality of the object-oriented System. Many metrics relating to product quality have proved their value for system maintenance and modification. The object-oriented metrics criteria selected are used to evaluate the system attributes [18].

Kajla, P. in thesis, recommended a new metric as Nested Class Complexity Metric (NCCM) to find the complexity of nested classes and outcome is compared with present available metrics. Nested classes are the general requirement in the programming like Java. These programming languages facilitate Nested Methods into the method of the same class [19].

Nicolaescu A., et al. Coupling is one of the most important properties that affect the quality of the design and implementation of a software system. In this work, review and critically analyze the developments in this domain by considering the most influential research addressing object-oriented software coupling [20].

Li, W. et al., software metrics have been analyzed in the procedural paradigm as a quantitative means of assessing the software development process as well as the software quality of products. Many studies have validated that various software metrics are important indicators of maintenance effort in the procedural paradigm [21].

Kumar, L., et al. empirically found the association of present class level metrics with a software quality factor as maintainability. Various object-oriented metrics has been utilized to give required input to design the models for forecasting maintainability quality factor using Neuro-Genetic algorithm [22].

III. PROBLEM STATEMENT

Failure rates and software maintenance cost have been extended due to different problems of inefficiency and non-reliability. Complexity has been constituted in object-oriented software’s due to high-coupled and low cohesive design. Further effective metric tools, techniques, design and theory are mandatory to utilize through actual use of software metrics to attain quality intention with perfection and reliability in software growth.

IV. OBJECTIVES OF THE STUDY

A. To interpret and scrutinize various Object Oriented Metrics to clear ideation of computation opinions and to explore the base for software quality framework.

B. To propose Metric Quality Design for productive software measurement tool to ensure standard and exposition of factors influencing quality of Object Oriented Software Development.

V. RESEARCH METHODOLOGY

Analytical research utilized for literature interpretation of existing object-oriented metrics proposed by different researchers, and make an evaluation of the metric quality design for software growth. In analytical research, facts and information already available and analyze them to
interpret results for future work. Conceptual and Experimental research is also used for generation of design framework and to reinterpret existing ones with results. Data sources for research are reputed research papers, reference books, review papers, thesis, object oriented software’s testing tools and internet.

VI. INTERPRETATION OF OBJECT ORIENTED METRICS FOR SOFTWARE COMPUTATION

Kenneth Morris research in thesis as "Metrics for Object Oriented Software Development Environments (1989)", due to restricted literature on object oriented software design and coding at that time his research was centered around productivity software metrics instead of software complexity metrics. The outcome of the literature review called "productivity impact variables". These are Maintainability, Reusability, Extensibility, Testability, Comprehensibility, Reliability and Author ability.

Object Oriented Metrics by Shyam R. Chidamber and Chris F. Kemerner is the intellectual research in object oriented design analysis in 1994. These software metrics are also called as “C-K metrics” [11].

Weyuker’s 2nd property and 8th property is instinctive utilized for different object oriented software metrics. They have explained six object oriented metrics for software measurement and computation [11,23].

**Metric :1 Weighted Methods per Class (WMC)**

WMC is computed as a total of the complexities of all different class functions or methods. Let a class M1 with class functions or methods N1, N2, . . . , Nn and c1 . . . cn be the static complexity of class function or method. Then

$$\text{Weighted Method per Class} = \sum_{i=1}^{n} c_i$$

All the functions of WMC are deemed to be uniform, then WMC = n, then no of functions are weighted methods per class.

**Metric :2 Depth of Inheritance Tree (DIT)**

DIT is calculated as the largest length from the node to the root of the tree in class.

In project’s, when Depth of Inheritance is maximum, then probability of failure and errors occurrence will be maximum.

DIT metric meets the Weyuker’s properties 1,2,3,4,5 and property 6 is not fulfilled by DIT metric.

**Metric :3 Number of Children (NOC)**

NOC is computed as total of immediate inherited classes subordinated to a class. NOC metric is a computation of no of derived classes that are going to inherit the methods of the super class. The reusability factor maximum with increase of NOC metric.

**Metric :4 Coupling between object classes (CBO)**

Coupling explores communication between these object modules of classes. When different class methods declared in one class use methods or instance variables of the other class are said to be coupled. High level of CBO metric computation shows weak outcomes and more rework effort is required to do.

**Metric :5 Lack of Cohesion in Methods (LCOM)**

Cohesion describes that object modules should be independent to process. Lack of Cohesion (LCOM) compute the dissimilarity of functions or methods in a class by instance attributes. High cohesion indicates better class subdivision. Lack of Cohesion metric is measure the no of method pairs whose similarity is 0 minus the method pairs whose similarity is not zero.

**Metric :6 Response for a Class (RFC)**

It is explained as number of class methods in the set of all class methods that can be called in result or response to a message sent to an object of a class. Response of a class includes methods invoked from outside the class. It is a computation of association between class and other classes. If value of RFC metric is maximum in project’s, then testing of class become much complicated.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>C-K Metric</th>
<th>Object Oriented Attribute</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Weighted Methods per Class (WMC)</td>
<td>Class</td>
</tr>
<tr>
<td>2</td>
<td>Depth of Inheritance Tree (DIT)</td>
<td>Inheritance</td>
</tr>
<tr>
<td>3</td>
<td>Number of Children (NOC)</td>
<td>Inheritance</td>
</tr>
<tr>
<td>4</td>
<td>Coupling between object classes (CBO)</td>
<td>Coupling</td>
</tr>
<tr>
<td>5</td>
<td>Lack of Cohesion in Methods (LCOM)</td>
<td>Cohesion</td>
</tr>
<tr>
<td>6</td>
<td>Response for a Class (RFC)</td>
<td>Class</td>
</tr>
</tbody>
</table>
**Metric :2 Attribute Hiding Factor (AHF)**  
Attribute Hiding Factor explored as the ratio of total of the invisibilities of all class attributes to the total number of class attributes declared in the software under consideration [25].

**Metric :3 Method Inheritance Factor (MIF)**  
Method Inheritance Factor is the ratio of the total of the inherited functions or methods in all classes of the software under consideration to the total number of available all classes' functions.

**Metric :4 Attribute Inheritance Factor (AIF)**  
Attribute Inheritance Factor is the ratio of the total addition of all class inherited attributes of the software under consideration to the total numbers of available all classes attributes.

**Metric :5 Polymorphism Factor (PF)**  
Polymorphism Factor states as the ratio of the actual number of different possible polymorphic situation for class Mi to the maximum number of possible distinct polymorphic situations for class Mi.

**Metric :6 Coupling Factor (CF)**  
Coupling Factor describes as the ratio of the maximum possible number of couplings in the software to the actual number of couplings not imputable to inheritance.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Metrics for Object Oriented Design</th>
<th>Object Oriented Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Method Hiding Factor (MHF)</td>
<td>Information Hiding</td>
</tr>
<tr>
<td>2</td>
<td>Attribute Hiding Factor (AHF)</td>
<td>Encapsulation</td>
</tr>
<tr>
<td>3</td>
<td>Method Inheritance Factor (MIF)</td>
<td>Inheritance</td>
</tr>
<tr>
<td>4</td>
<td>Attribute Inheritance Factor (AIF)</td>
<td>Inheritance</td>
</tr>
<tr>
<td>5</td>
<td>Polymorphism Factor (PF)</td>
<td>Polymorphism</td>
</tr>
<tr>
<td>6</td>
<td>Coupling Factor (CF)</td>
<td>Coupling</td>
</tr>
</tbody>
</table>

Lorenz and Kidd described six object oriented metrics to find assessment of object oriented software quality. These object oriented metrics are classified into three types as size, inheritance, internal and external based measurement.

Size based metrics for class points on addition of class attributes and class operations. Inheritance based metrics points on the class function or method in which operations are reused through class hierarchy. Internal based metrics follows cohesion and code oriented issue of a class. External metrics focus on coupling and reuse of class [5,23].

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>L &amp; K Metrics</th>
<th>Object Oriented Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Attribute Count (AC)</td>
<td>Class</td>
</tr>
<tr>
<td>2</td>
<td>Method Count (MC)</td>
<td>Class</td>
</tr>
<tr>
<td>3</td>
<td>Number of Operation Overridden by Subclass (NOO)</td>
<td>Inheritance</td>
</tr>
<tr>
<td>4</td>
<td>Specialization Index (SI)</td>
<td>Inheritance</td>
</tr>
<tr>
<td>5</td>
<td>Number of Operations Added be a Subclass (NOA)</td>
<td>Inheritance</td>
</tr>
<tr>
<td>6</td>
<td>Average Number of Parameters per method (ANP)</td>
<td>Class</td>
</tr>
</tbody>
</table>
VII. METRIC QUALITY DESIGN FOR REFINEMENT IN OBJECT ORIENTED SOFTWARE DEVELOPMENT

Better measurements and better metrics are quality stone to software growth with distinction [26]. Object Oriented Metrics are significant for ensuring software quality and used by software development companies [27,32]. Different object oriented metrics proposed by various researchers to measure the software productiveness and efficiency. Metric Quality Design proposed based on object oriented metrics comprehensive interpretation to deliver standard software. Different metric consequences are discussed in this and considered for development of object oriented software and results explored. This design is suggested for measurement tools and software testing team, to consider these consequences while developing software. High cohesive and low coupling design is important for object oriented software development [28,33]. Cohesion describes that object modules should be independent to process [29]. Coupling explores communication between these object modules [34]. Metric testing tool can be developed based on this framework for object oriented software measurement and quality results.

Table 4 – Metrics Results for Object Oriented Software Development

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Metrics Consequences</th>
<th>Results</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Decision making</td>
<td>Metrics are helpful to software engineers to take correct decision for software development and maintenance.</td>
</tr>
<tr>
<td>2</td>
<td>Significant Improvement of software</td>
<td>Metrics makes important changes in software to update new version based on user requirements and needs.</td>
</tr>
<tr>
<td>3</td>
<td>Reliability as failure free software</td>
<td>Metrics ensure reliability as error free software to customer.</td>
</tr>
<tr>
<td>4</td>
<td>Estimating the effort involved for maintenance</td>
<td>Metrics are helpful in estimating cost and feasibility of software product as well as for maintenance.</td>
</tr>
<tr>
<td>5</td>
<td>Quality of the design</td>
<td>Metrics are used for making good quality software based on correct measurements.</td>
</tr>
<tr>
<td>6</td>
<td>Measure complexity of the code</td>
<td>Metrics ensure to measure complexity level of software to make it high cohesive and low coupled design.</td>
</tr>
<tr>
<td>7</td>
<td>Prediction of faults</td>
<td>Metrics helps to predict failures and errors to make accurate software code.</td>
</tr>
<tr>
<td>8</td>
<td>Process efficiency</td>
<td>Metrics makes software development process efficient as per correct user requirements.</td>
</tr>
<tr>
<td>9</td>
<td>Product Effectiveness</td>
<td>Metrics ensure quality product by removing ambiguities and flaws in design.</td>
</tr>
</tbody>
</table>

In fig 2. Metric Quality Design framework suggested with different components for metrics tool generation and metric consequences interpreted by software testing team for quality of object oriented design. Team will comprehensively analyze the factors of quality and consider for design of software. Object and module analysis done on different real world entities on source code and software module analysis done on whole code, after this object interface analysis done for measuring coupling between objects. All inputs to object oriented metric analyzer for comprehensive evaluation of quality of software with high cohesion and low coupling.

Object Oriented Software Quality is a procedure that evaluates, assesses, and improves the performance of real world entity applications [30,31].

It is defined as the degree to which software meets requirements for reliability, maintainability, portability as contrasted with functional, performance, and interface requirements that are satisfied as a result of software engineering in context of real world entities i.e. objects [35,37]. The McCall et al., factor model provides a software quality factors, practical, up-to-date method for classifying software requirements. In fig. 3 different software quality
attributes explored with quality levels for object oriented software development. Low and medium quality level ensures low quality software due to limited features. High and very high quality level ensures good software quality, but ultra-high quality level ensures excellent software quality including all features related to software in future use. It involves user requirements and performance requirements, documentation and all well engineered qualities required for object oriented software [36,38]. Object Oriented Testing describes degree to which a user understands design and development of object oriented systems [36,38].

Object Oriented Metrics performed a vital role in software measurement and in helping software managers to understand design and development of object oriented software to meet its requirements as failure free software. If software is not error free, it is unreliable.

Object Oriented Metrics performed a vital role in software measurement and in helping software managers to understand design and development of object oriented software. In this design, different metric consequences discussed and considered for quality growth of object oriented software and results explored. In future research work can be to develop productive software metric tool or analyzer based on this framework for improvement of time schedule availability, reduce maintenance cost, enhance reliability and standard quality growth.

Table 5 – Analysis of Quality factors influencing Software Development

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Factors</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Correctness</td>
<td>Correctness deals to which a program satisfies its user requirement specifications. If software does not work as required, it has no worth.</td>
</tr>
<tr>
<td>2</td>
<td>Reliability</td>
<td>Reliability defines how well the software meets its requirements as failure free software. If software is not error free, it is unreliable.</td>
</tr>
<tr>
<td>3</td>
<td>Extensibility</td>
<td>Extensibility is the ability of the software to be upgraded beyond the functionality of the original software. If software coding is not able to update by adding new features, it is wasteful.</td>
</tr>
<tr>
<td>4</td>
<td>Portability</td>
<td>Portability describes requirement to transfer the software from one configuration machine to another machine. If software is not able to install any other machine, it is has no value.</td>
</tr>
<tr>
<td>5</td>
<td>Usability</td>
<td>Usability or the effort required locating and fixing failures in programs. If software is not user friendly, then it is difficult for user to handle.</td>
</tr>
<tr>
<td>6</td>
<td>Reusability</td>
<td>Reusability is the extent to which parts of the software can be reused in other related software. If software is not reusable, it is waste.</td>
</tr>
<tr>
<td>7</td>
<td>Testability</td>
<td>Testability is required to test to ensure that the software performs its required function. If testing is not able to do, it makes software failures.</td>
</tr>
<tr>
<td>8</td>
<td>Maintainability</td>
<td>Maintainability is the effort required to update the software. If software is not able to add new features, it is wasteful.</td>
</tr>
<tr>
<td>9</td>
<td>Efficiency</td>
<td>Efficiency is concerned with all issues in the execution of software; it includes response time, memory requirement, and throughput of system fast. If software is not making computer fast, it is wasteful.</td>
</tr>
</tbody>
</table>

VIII. CONCLUSION AND FUTURE WORK

Object Oriented Metrics performed a vital role in software measurement and in helping software managers to understand design and development of object oriented software. Object Oriented Software Development helps in designing and creating all real world entities and use of these metrics to evaluate quality improvements. Failure rates and Maintenance cost have been increased due to complexity and unreliability. There is need of high cohesion and low coupling in object oriented software to ensure reliability and effectiveness. This work has analyzed different object oriented metrics given by different researchers for improving further quality of design. Further Metric Quality Design framework suggested based on metrics interpretation to deliver object oriented quality software. In this design, different metric consequences discussed and considered for quality growth of object oriented software and results explored. In future research work can be to develop productive software metric tool or analyzer based on this framework for improvement of time schedule availability, reduce maintenance cost, enhance reliability and standard quality growth.

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