

# Predicting Adaptability Level of Object-Oriented Software Using Metrics and Threshold Values.

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## ABSTRACT

In recent years, adaptability has become so important in various disciplines and a key characteristic of well-designed applications because modern software systems are expected to service swiftly revolutionizing business environments. Much effort have been invested in the development of object oriented design metrics to measure software properties such as coupling, cohesion and inheritance, but metrics to be used by software developers to predict, at the coding phase, the extent to which object oriented software adapt is needed.

In this work a software analyzer is used to measure the values of some internal properties of object oriented software using combination of associated object oriented design metrics. Threshold values of these object oriented design metrics are grouped into levels taking into consideration the desirable values of the internal software properties.

The measured values are matched against these threshold values and the level of each attribute is noted. Decisions rules are formulated and used in conjunction with binary logic combination of the possible internal software properties to aid predict adaptability level of a given software. Analysis is carried out on 12 open source Java projects and their adaptability levels are noted. The analysis revealed that source codes with low coupling, high cohesion, low inheritance and low complexity easily adapt to new operating environment with little or no modifications to the source codes.

(Keywords: adaptability level, software metrics, internal software attributes, threshold values, software analyzer)

## INTRODUCTION

One of the fastest growing areas in the Information Technology (IT) industry is the area of Software; its products and technologies. Our modern society is becoming maximally dependent on software [19]. As many individuals, corporate organizations and even government use several software products to enhance effectiveness of their operations, the demand for quality software continues to increase. Therefore there is need to improve software productivity and quality.

The term “quality software” is seen to comprise software products such as adaptability, completeness, maintainability and understandability [12]. Software products are intended to be adaptable. Therefore there is need to predict the adaptability level of any developed software.

Reference [11] described software quality in terms of six (6) quality attributes – Functionality, Reliability, Usability, Efficiency, Maintainability and portability. Sub-characteristics of portability are adaptability, usability, co-existence, and replicability [11]. Portability simply means the ease with which a software system can be transferred from one platform to another. It is therefore the ability of code-base feature to reuse the already existing code rather than writing new code when transferring software from one environment to another. What therefore affects portability also affects adaptability and other sub-attributes of portability.

The realization of any of the sub-characteristics can be determined using metrics [31]. These sub-characteristics can be termed external quality attributes because they relate with the behavior of the software and as such cannot be directly measured but can only be measured through

internal quality attributes such as coupling, cohesion, complexity etc. [21]

Measurement of external software attribute such as adaptability can be done at any phase of software development lifecycle. In this work, the measurement of adaptability is done at the source code phase. Researchers [27] investigated the result of object oriented design software metrics on fault- proneness for java applications which were empirically analyzed and tested using software tool at the source code level. Research conducted by [1] also analyzed the complexity of java programs, at source code level, using object oriented software metrics.

Metrics measure quantitatively the extent to which an object, system, component, method or procedure contain a given property. It assigns a value (number or symbol) to the properties of entities in the real life scenario based on distinctly formulated and defined set of rules [9]. Metrics help software experts and engineers to accurately measure and predict software processes and necessary resources needed for a project to produce the required result. It also predicts the products relevant for a software development job [2]. Software metrics are therefore used as pointers (estimators/predictors) to external quality attributes.

The objective of this work is to develop and implement processes to predict adaptability level of object-oriented software using software metrics. Two metrics are used for each associated internal software properties to ensure accurate property measurement. The threshold values of these metrics are indicated and properly categorized into three levels of adaptability prediction. Rules are formulated using the threshold values to aid in proper prediction of adaptability level of object oriented software.

Since most metrics do not provide practical support to software designers and developers and lack qualitative as well as quantitative evaluation techniques [9, 1], this approach predicts adaptability level in object oriented software giving practical support to software developers.

In order to establish relationship between design construct and software quality, the influence of design constructs on software quality have been examined and revealed that cohesion, coupling, inheritance, encapsulation and complexity affect quality attributes to some extent. Software

engineering experts assume that design with low coupling, high cohesion, less complexity and low inheritance leads to products that are of high quality – better testability, readability, reliability, maintainability etc. [27].

## **ADAPTABILITY, ITS NEED AND SOME TERMS**

Adaptability as one of the properties of object-oriented software is among the most significant non-functional requirements in software [22]. Adaptability is one of the key considerations of well-designed applications in recent years because present day software systems must be able to service the changing business environments rapidly, efficiently and with robust reliability over a long time interval. If a system is designed without bearing in mind adaptability, the system will degrade and malfunction in the face of continuous software requirements changes.

Several authors define adaptability differently. Reference [10] defines adaptability as “the ease with which a system or component can be modified for use in applications or environments other than those for which it was specifically designed”. Reference [23] views adaptability as modification of behavior in response to environment changes. Reference [24] defines adaptability as amendment of the changing requirements. Adaptability is the level of ease a system shows in being adjusted to meet a modified requirement. It therefore characterizes the ability of a system to still function properly in an event of change to new specifications or operating environment. Adaptability is the level to which software adjusts to change in its environment. It is vital for the survival, functionality and success of any software system and should therefore be optimized, even at the expense of other software quality characteristics.

For a software system to still function, it must undergo adaptive maintenance, which is the correction done on a software code or product after it might have been delivered to make it useful in a modified environment. As time elapses, the software initial environment in which the software was developed for may change. These may include the CPU, operating platform, product characteristics etc. [26]. This environmental change is mostly due to changes in technology, organizational goal and structure, human feelings and needs, etc. [16]. Other changes may be as a result of change in

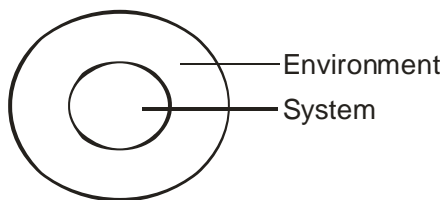
customer requirements, need for new software development, modification of software features, bugs and defect detection and fixing during the maintenance phase of software life cycle. Therefore, software adaptability measurement is a key concern to software designers, developers and other personnel within the software engineering community.

Adaptability metrics therefore measures how flexible and adjustable a system is to changes within its operating environment [8]. It measures the ease of change during the project development phase or in a postmortem fashion. This is the aim of this work.

To really understand what adaptability of a software system means, the definitions of the following terms are vital:

1. **System (S)** – An assembly of components connected together in an organized way and separated from its environment [4]. There is an interaction between a system and its environment.
2. **Environment (E)** – This is the space in which a system is settled. Environment is actually another system which surrounds the actual system. The subset of complete environment which interacts with the system is Relevant Environment ( $E_R$ ) while the subset of the complete environment which has no interaction with the system is called the Irrelevant Environment ( $E_I$ ). Environment is therefore Relevant Environment Union Irrelevant Environment.

$$E = E_R \cup E_I \quad (1)$$



**Figure 1:** Relationship between System and Environment.

3. **Domain (D)** - The system under consideration together with the Relevant Environment forms the Domain.

$$D = S \cup E_R \quad (2)$$

From Figure 1, it can be deduced that System = Domain.

4. **Adaptation** - Change in the system to accommodate change in its environment. Adaptation of a software system (S) is caused by change ( $\delta_E$ ) from an old environment (E) to a new environment (E') and results in new system (S') that ideally meets the need of the new environment.

## INTERNAL SOFTWARE ATTRIBUTES

Internal software attributes are those that can be measured purely in terms of the product, process or resource itself [21]. The internal software attributes used in this work are Coupling, Cohesion, Inheritance and Complexity. Their definitions are highlighted below:

- **Coupling:** Amount of connections between classes [30].
- **Cohesion:** This is the extent to which the individual components of software are needed to perform the same task [21]. Cohesion measures the degree of connectivity among the elements of a single class or object [6].
- **Inheritance:** This is the sharing of attributes and operations among classes based on a hierarchical relationship. Inheritance therefore occurs in all levels of a class hierarchy.
- **Complexity:** This describes the interactions between numbers of entities. As the number of entities increases, the number of interactions between them would increase exponentially, and it would get to a point where it would be impossible to know and understand all of them.

Suite of metrics by [30] is used in this study because of their wide acceptance among the engineering community [15]. Two other metrics: Number of Methods (NOM) and Lack of Cohesion in Methods 2 (LCOM2) are added to help in accurate measurement of the internal software properties.

The metrics suite by [30] consists of Coupling Between Objects (CBO), Response for a Class (RFC), Lack of Cohesion in methods1 (LCOM1), Depth of Inheritance Tree (DIT), Number of Children (NOC) and Weighted Methods per Class (WMC). Table 1 shows the metrics, their definition and their effect on adaptability.

## RELATED WORK

Several software adaptability metrics have been developed using different techniques as architecture-based technique, component-based technique, dynamic adaptation technique etc.

Reference [7] proposed a component-based architecture by providing an adaptable interface to each component. The code in the adaptable interface can be changed as required to achieve the needed adaptation without making any change to the component.

Reference [22] modeled software adaptability as Non-Functional Requirement (NFR). Through this approach, consideration of design alternatives, analysis of tradeoffs, and rationalization of design decisions are all carried out in relation to the stated goals. Adaptation is supported at the architectural level by using NFRs framework which allows for decomposition of the NFR adaptability depending on the domain or the application and permits criticalities to be allocated to different NFRs of the decomposition.

Reference [16] proposed a framework called POMSAA (Process-Oriented Metrics for Software Architecture Adaptability) which aims at providing numeric scores representing the adaptability of software architecture as well as the intuitions behind these scores, utilizing Softgoal Interdependency Graph (SIG).

Reference [22] introduced two high level metrics to measure the adaptability of software. They defined an Element Adaptability Index (EAI) for each software unit. EAI was set to 1 for adaptable elements and 0 for non-adaptable elements. EAI can be measured at different levels of software granularity. Based on EAI, two metrics of Architecture Adaptability Index (AAI) and Software Adaptability Index (SAI) are calculated.

Considering the choice and validation of internal quality attributes, a number of researches have been done. Table 2 classifies internal quality attributes and external quality attribute(s) they affect.

## RESEARCH METHODOLOGY

The method adopted to accomplish the objectives of this work follows a systematic approach:

- (a) Using our developed software analyzer to measure the values of coupling, cohesion, inheritance and complexity of a source code using associated object oriented design metrics.
- (b) Threshold values of these object oriented design metrics are grouped into adaptability levels taking into consideration the desirables values of the internal software properties.
- (c) Values of the internal software properties are matched against estimated threshold values and computed for 12 different open source codes.
- (d) Rules are used to formulate the level of each property in the source code and the adaptability levels of the software for appropriate predictions.

## THRESHOLD VALUES

In order to determine the level in which a software possesses the value of the selected internal software properties, the value of each property is measured against a threshold. Low means the value is below a threshold while high means above the threshold. Thresholds are defined as "heuristic values used to set ranges of desirable and undesirable metric values for measured software. These thresholds are used to identify anomalies which may or may not be an actual problem [20]. Threshold values for the selected metrics are shown in Table 3.

**Table 1:** Metrics, Definition and their Effects on Adaptability (Sources: [2], [5], [1] and [13]).

| PROPERTIES  | METRICS | DEFINITION   | EFFECT ON ADAPTABILITY  |
|-------------|---------|--|---|
| COUPLING    | CBO     | The number of distinct non-inheritance related classes to which a given class is coupled. It is the number of methods that can be called in response to a message in a class.  | <ul style="list-style-type: none"> <li>i. Too much coupling between objects prevents reuse, thereby reducing the probability of adaptability</li> <li>ii. The larger the number of couples the higher the sensitivity to changes and difficulty of maintenance. Difficult to maintain means less adaptability.</li> </ul>   |
|             | RFC     | Defined as $ RS $ where RS is the response set for a class. The response set for a class can be expressed as:<br>$RS = \{M\} \cup \{R_i\}$<br>Where:<br>$\{R_i\}$ = set of methods called by method i<br>$\{M\}$ = set of all methods in the class.  | <ul style="list-style-type: none"> <li>i. If the number of methods called in response to a message received by an object is large, then maintenance and testing becomes difficult which results in less adaptability</li> <li>ii. The larger the number of methods that can be called from a class, the greater the complexity of the class thereby reducing adaptability.</li> </ul>           |
| COHESION    | LCOM1   | The count of the number of method pairs whose similarity is zero minus the count of method pairs whose similarity is not zero. Let $ P $ be the number of null intersections between instance variables. Let $ Q $ be the number of non-empty intersections between instance variable sets, then:<br>$LCOM =  P  -  Q $ is $ P  >  Q $<br><br>$LCOM = 0$ Otherwise.  | <ul style="list-style-type: none"> <li>i. Cohesiveness of methods within a class is desirable because it promotes encapsulation and increase adaptability</li> <li>ii. A measure of disparateness of methods helps identify flaws in the design of classes</li> <li>iii. Low cohesion increases complexity thereby reducing adaptability level.</li> </ul>                                      |
|             | LCOM2   | The percentage of methods that do not access a specific attribute averaged over all attributes in the class.<br>$LCOM2 = 1 - \frac{\sum(mA)}{m*a}$<br>Where:<br>m = number of methods in class.<br>a = number of attributes in class.<br>mA = number of methods that access an attribute.<br>$\sum(mA)$ = sum of mA over attributes of a class.  | <ul style="list-style-type: none"> <li>i. A higher value of LCOM2 indicates decreased encapsulation and increased complexity, thereby increasing the likelihood of errors. This affects adaptability negatively.</li> </ul>   |
| INHERITANCE | DIT     | It calculates the distance to which a class is declared in the inheritance hierarchy. It also counts the number of ancestor classes that can potentially affect this class.  | <ul style="list-style-type: none"> <li>i. The deeper a class is in the hierarchy, the greater the number of methods it is likely to inherit, making it more complex thus having a potential impact on adaptability.</li> <li>ii. Deeper trees constitute greater design complexity since more methods and classes are involved. This also affects adaptability negatively.</li> </ul>           |
|             | NOC     | It counts the number of sub-classes that are going to inherit the methods of the parent class. That is the number of immediate classes subordinated to a class in the class hierarchy.   | <ul style="list-style-type: none"> <li>i. The greater the number of children the greater the reuse, since inheritance is a form of reuse. This positively affects adaptability.</li> </ul>  |
| COMPLEXITY  | WMC     | Traditionally, this measures the complexity of an individual class (weighted sum of all the methods in a class). It calculates all declared methods and constructors of class.<br>Consider a class $C_1$ with methods $M_1 \dots M_n$ . Let $C_1$ to $C_n$ be complexity of the methods, then:<br>$WMC = \sum_{i=1}^n C_i$<br>Where C is complexity of methods.<br>If WMC is unity, then WMC is the number of methods per class. | <ul style="list-style-type: none"> <li>i. The number of methods and the complexity of methods involved is a determinant of how much time and effort is required to maintain software thereby making it adaptable.</li> <li>ii. Classes with large number of methods are likely to be more application specific thereby limiting the possibility of reuse in a different environment.</li> </ul> |
|             | NOM     | The number of methods implemented in a given class.  | <ul style="list-style-type: none"> <li>i. Since NOM includes methods that are declared and those that are not declared. This truly reveals software complexity. Higher the complexity, lower its likelihood to adapt.</li> </ul>  |



**Table 2:** Classification of Internal and External Quality Attributes.

| INTERNAL ATTRIBUTES                           | EXTERNAL ATTRIBUTES   | SOURCE |
|---|---|--------|
| Coupling                                      | Maintainability   | [33]   |
| Coupling<br>Cohesion                          | Maintainability   | [3]    |
| Cohesion<br>Size metrics<br>Complexity metric | Maintainability   | [29]   |
| C & K metrics<br>MCC, LOC                     | Reusability   | [25]   |
| C & K metrics<br>FOUT, NOM, LOC               | Adaptability,<br>Completeness,<br>Maintainability<br>Understandability<br>Reusability,<br>Testability | [14]   |
| C & K metrics<br>FOUT, NOM, LOC               | Adaptability,<br>Maintainability<br>Understandability<br>Reusability,<br>Testability                  | [18]   |
| C & K metrics<br>FOUT, NOM, LOC               | Adaptability,<br>Completeness,<br>Maintainability<br>Understandability<br>Reusability,<br>Testability | [15]   |

**Table 3:** Metrics Threshold Values.

| PROPERTIES  | METRICS | THRESHOLD VALUE | SOURCE       |
|-------------|---------|-----------------|--------------|
| Coupling    | CBO     | 5               | [17]<br>[28] |
|             | RFC     | 100             | [17]<br>[28] |
| Cohesion    | LCOM1   | 1               | [5]          |
|             | LCOM2   | 2               | [5]          |
| Inheritance | DIT     | 6               | [5]          |
|             | NOC     | 6               | [5]          |
| Complexity  | WMC     | 100             | [17]<br>[28] |
|             | NOM     | 20              | [31]         |

## DECISION RULES

To determine whether the level of these attributes in a given software is above or below the threshold, rules are employed. Low (0) is for value below the threshold and High (1) is for the value above the threshold.

**Determining Attribute Levels:** The rules for determining the level of Coupling, Cohesion, Inheritance and Complexity is given thus:

- i. Low Coupling will occur only when  $CBO \leq 5$  and  $RFC \leq 100$ . Other conditions will yield High Coupling.
- ii. High Cohesion will occur only when  $LCOM1 \leq 1$  and  $LCOM2 \leq 2$ . Other conditions will yield Low Cohesion.
- iii. Low Inheritance will occur only when  $DIT \leq 6$  and  $NOC \leq 6$ . Other conditions will yield High Inheritance
- iv. Low Complexity will occur only when  $WMC \leq 100$  and  $NOM \leq 20$ . Other conditions will yield High Complexity.

**Determining Adaptability Levels (AL) for each Attribute:** Before determining adaptability levels, the desirable condition (level) for the selected internal software properties is known. Low coupling, high cohesion, low inheritance and low complexity are desirable conditions for effective adaptability of object oriented software.

Table 4 shows how threshold values are grouped for each level of adaptability for a particular desired condition. The threshold values for the different adaptability levels in Table 4 are used in establishing rules for adaptability levels of each of the software properties. The adaptability levels are Adaptable, Fairly Adaptable and Poorly Adaptable.

The rules are written out below:

### COUPLING

If  $CBO = 1$  to  $3$  and  $RFC = 1$  to  $69$   
Then Coupling = Adaptable

If  $CBO = 1$  to  $3$  and  $RFC = 70$  to  $100$   
Then Coupling = Fairly Adaptable

If  $CBO = 1$  to  $3$  and  $RFC > 100$   
Then Coupling = Poorly Adaptable

If  $CBO = 4$  to  $5$  and  $RFC = 1$  to  $69$   
Then Coupling = Adaptable

If  $CBO = 4$  to  $5$  and  $RFC = 70$  to  $10$   
Then Coupling = Fairly Adaptable

**Table 4:** Threshold Ranges for Adaptability Levels.

| DESIRABLE FEATURE | METRICS | ADAPTABLE | FAIRLY ADAPTABLE | POORLY ADAPTABLE |
|-------------------|---------|-----------|------------------|------------------|
| Low Coupling      | CBO     | 1 – 3     | 4 – 5            | > 5              |
|                   | RFC     | 1 – 69    | 70 – 100         | > 100            |
| High Cohesion     | LCOM1   | 1         | -                | > 1              |
|                   | LCOM2   | 0 – 1     | 2                | > 2              |
| Low Inheritance   | DIT     | 0 – 4     | 5 – 6            | > 6              |
|                   | NOC     | 0 – 4     | 5 – 6            | > 6              |
| Low Complexity    | WMC     | 1 – 69    | 70 – 100         | > 100            |
|                   | NOM     | 0 – 10    | 11 – 20          | > 20             |

If CBO = 4 to 5 and RFC > 100  
Then Coupling = Poorly Adaptable

If CBO > 5 and RFC = 1 to 69  
Then Coupling = Adaptable

If CBO > 5 and RFC = 70 to 100  
Then Coupling = Fairly Adaptable

If CBO > 5 and RFC > 100  
Then Coupling = Poorly Adaptable

### COHESION

If LCOM1 = 1 and LCOM2 = 0 to 1  
Then Cohesion = Adaptable

If LCOM1 = 1 and LCOM2 = 2  
Then Cohesion = Fairly Adaptable

If LCOM1 = 1 and LCOM2 > 2  
Then Cohesion = Poorly Adaptable

If LCOM1 > 1 and LCOM2 = 0 to 1  
Then cohesion = Adaptable

If LCOM1 > 1 and LCOM2 = 2  
Then Cohesion = Fairly Adaptable

If LCOM1 > 1 and LCOM2 > 2  
Then Cohesion = Poorly Adaptable

### INHERITANCE

If DIT = 0 to 4 and NOC = 0 to 4  
Then Inheritance = Adaptable

If DIT = 0 to 4 and NOC = 5 to 6  
Then Inheritance = Fairly Adaptable

If DIT = 0 to 4 and NOC > 6  
Then Inheritance = Poorly Adaptable

If DIT = 5 to 6 and NOC = 0 to 4  
Then Inheritance = Adaptable

If DIT = 5 to 6 and NOC = 5 to 6  
Then Inheritance = Fairly Adaptable

If DIT = 5 to 6 and NOC > 6  
Then Inheritance = Poorly Adaptable

If DIT > 6 and NOC = 0 to 4  
Then Inheritance = Adaptable

If DIT > 6 and NOC = 5 to 6  
Then Inheritance = Fairly Adaptable

If DIT > 6 and NOC > 6  
Then Inheritance = Poorly Adaptable

### COMPLEXITY

If WMC = 1 to 69 and NOM = 0 to 10  
Then Complexity = Adaptable

If WMC = 1 to 69 and NOM = 11 to 20  
Then Complexity = Fairly Adaptable

If WMC = 1 to 69 and NOM > 20  
The Complexity = Poorly Adaptable

If WMC = 70 to 100 and NOM = 0 to 10  
Then Complexity = Adaptable

If WMC = 70 to 100 and NOM = 11 to 20  
Then Complexity = Fairly Adaptable

If WMC = 70 to 100 and NOM > 20  
Then Complexity = Poorly Adaptable

If WMC > 100 and NOM = 0 to 10  
Then Complexity = Adaptable

If WMC > 100 and NOM = 11 to 20  
Then Complexity = Fairly Adaptable

If WMC > 100 and NOM > 20  
Then Complexity = Poorly Adaptable

### Determining Adaptability Level for entire Software:

The adaptability levels for a given software are Poorly Adaptable (1), Fairly Adaptable (2) and Adaptable (3). The possible combinations for levels of the properties are shown in Table 5.

**Table 5:** Possible Combinations for Property Level.

| S/N | COU | COH | INH | COM |
|-----|-----|-----|-----|-----|
| 1   | 0   | 0   | 0   | 0   |
| 2   | 0   | 0   | 0   | 1   |
| 3   | 0   | 0   | 1   | 0   |
| 4   | 0   | 0   | 1   | 1   |
| 5   | 0   | 1   | 0   | 0   |
| 6   | 0   | 1   | 0   | 1   |
| 7   | 0   | 1   | 1   | 0   |
| 8   | 0   | 1   | 1   | 1   |
| 9   | 1   | 0   | 0   | 0   |
| 10  | 1   | 0   | 0   | 1   |
| 11  | 1   | 0   | 1   | 0   |
| 12  | 1   | 0   | 1   | 1   |
| 13  | 1   | 1   | 0   | 0   |
| 14  | 1   | 1   | 0   | 1   |
| 15  | 1   | 1   | 1   | 0   |
| 16  | 1   | 1   | 1   | 1   |

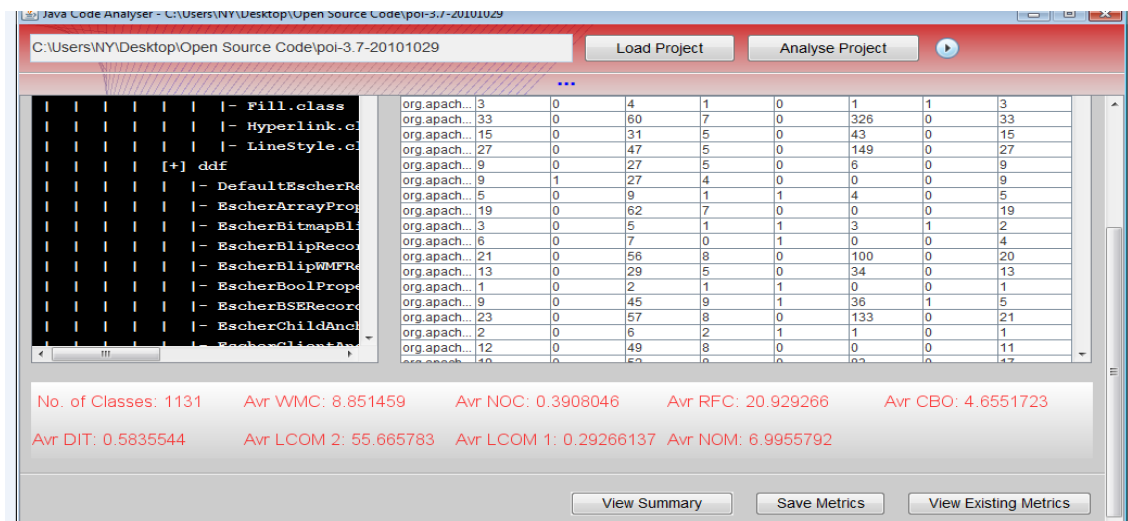
Taking into consideration the desirable level for each property, Table 5 is reduced to Table 6 where Y (yes) replaces the desirable value and N (no) replaces the undesirable value. These values are used to determine the Adaptability Level (A.L) of software.

### IMPLEMENTATION AND RESULT

Twelve (12) Java projects were loaded into our software analyzer for analysis of the source codes. Information such as number of classes, average values of CBO, RFC, LCOM1, LCOM2, DIT, NOC, WMC and NOM were extracted. Figure 2 shows the analysis of one of the projects (poi-3.7-2010 1029) while Figure 3 shows the metrics summary of the project, indicating the adaptability level for each of the properties in the analyzed project. Figure 4 shows the displayed threshold levels for the 12 projects.

**Table 6:** Values for Determining A.L.

| S/N | COU | COH | INH | COM | A.L |
|-----|-----|-----|-----|-----|-----|
| 1   | Y   | N   | Y   | Y   | 3   |
| 2   | Y   | N   | Y   | N   | 2   |
| 3   | Y   | N   | N   | Y   | 2   |
| 4   | Y   | N   | N   | N   | 1   |
| 5   | Y   | Y   | Y   | Y   | 3   |
| 6   | Y   | Y   | Y   | N   | 3   |
| 7   | Y   | Y   | N   | Y   | 3   |
| 8   | Y   | Y   | N   | N   | 2   |
| 9   | N   | N   | Y   | Y   | 2   |
| 10  | N   | N   | Y   | N   | 1   |
| 11  | N   | N   | N   | Y   | 1   |
| 12  | N   | N   | N   | N   | 1   |
| 13  | N   | Y   | Y   | Y   | 3   |
| 14  | N   | Y   | Y   | N   | 2   |
| 15  | N   | Y   | N   | Y   | 2   |
| 16  | N   | Y   | N   | N   | 1   |



**Figure 2:** Typical Example of Software Analysis.



| FEATURED METRICS            | PARAMETER 1                     | PARAMETER 2                     | OBSERVED LEVEL | NORMAL LEVEL |
|-----------------------------|---------------------------------|---------------------------------|----------------|--------------|
| COUPLING - Adaptable        | CBO[ 4.6551723 ] - Fairly Ad... | RFC[ 20.929266 ] - Adaptable    | LOW            | LOW          |
| COHESION - Fairly Adaptable | LCOM1[ 0.29266137 ] - Adap...   | LCOM2[ 55.665783 ] - Poorly ... | HIGH           | HIGH         |
| INHERITANCE - Adaptable     | DIT[ 0.5835544 ] - Adaptable    | NOC[ 0.3908046 ] - Adaptable    | HIGH           | LOW          |
| COMPLEXITY - Adaptable      | WMC [ 8.851459 ] - Adaptable    | NOM [ 6.9955792 ] - Adaptable   | LOW            | LOW          |

| PROJECT NAME     | COUPLING | COHESION | INHERITANCE | COMPLEXITY |
|------------------|----------|----------|-------------|------------|
| poi-3.7-20101029 | 0        | 1        | 1           | 0          |

Figure 3: Sample Metric Summary Output.

| SOURCE NAME           | COUPLING | COHESION | INHERITANCE | COMPLEXITY |
|-----------------------|----------|----------|-------------|------------|
| GrFingerJava          | 0        | 1        | 0           | 0          |
| Java 3D               | 0        | 1        | 1           | 0          |
| jmf                   | 0        | 1        | 0           | 0          |
| junit-3.8.1           | 0        | 1        | 0           | 0          |
| jxbrowser-4.3         | 0        | 1        | 0           | 0          |
| log4j-1.2.13          | 0        | 1        | 0           | 0          |
| MetricLib             | 1        | 1        | 0           | 0          |
| poi-3.7-20101029      | 0        | 1        | 1           | 0          |
| worldwind             | 0        | 1        | 1           | 0          |
| java_card_kit-classic | 0        | 1        | 0           | 0          |
| javacomm20win32       | 0        | 1        | 0           | 0          |
| jogl                  | 0        | 1        | 1           | 1          |

Figure 4: Threshold Values for the Projects.

**Result Explanations** – Using Table 6, it is seen that GrFingerJava will be adaptable to new environment with little or no modifications in the source code. The internal attributes of the source code are all below the threshold values. Jog1 will be fairly adaptable with a bit more modifications to the source code. Inheritance and Complexity values are above the threshold. The same explanations can be applied to all other projects.

## CONCLUSION

Since adaptability of object oriented software has become so important in recent years, it therefore becomes pertinent to predict adaptability level of any developed object oriented software.

This work has been able to predict adaptability level of 12 open source Java projects using metrics and threshold values. From this work it

can be concluded that source codes with low coupling, high cohesion, low inheritance and low complexity values adapt easily to new operating environment with little or no modifications to the source codes.

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## SUGGESTED CITATION

Akwukwuma, V.V.N. and E.N. Udo. 2015. "Predicting Adaptability Level of Object-Oriented Software Using Metrics and Threshold Values". *Pacific Journal of Science and Technology*. 16(2):124-134.

