

A COMPARISON OF CK AND MARTIN'S PACKAGE METRIC SUITES IN
PREDICTING PACKAGE REUSABILITY IN OPEN SOURCE OBJECT-
ORIENTED SOFTWARE

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A dissertation submitted in partial
fulfillment of the requirement for the award of the
Degree of Master of Computer Science (Software Engineering)



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Faculty of Computer Science and Information Technology
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MARCH 2016

DEDICATION

My family and my friends who are always with me.

May God blessed all of us always.



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ACKNOWLEDGEMENT

In the name of Allah, the most Beneficent, the most Merciful. In preparing this dissertation, I have been in touch with many people who have given me great support and beneficial ideas that have led to its success. At the very beginning, I would like to thank my parents for their unlimited support to me and my research, even though what I am studying was not the field they wanted me to go through, I thank them very much, and I ask Allah the Almighty to grant them Paradise.

I would also like to take this opportunity to sincerely thank my supervisor Dr. Hj. Mohd Zainuri Bin Saringat for his precious time, the facilities he offered me, and the great advice he gave me during this journey of my Master's project.

Not to forget my fellow postgraduate students who have spared some of their time praying for my success, thank you sincerely and wish you success in your lives.



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ABSTRACT

Packages are units that organize source code in large object-oriented systems. Metrics used at the package granularity level mostly characterize attributes such as complexity, size, cohesion and coupling. Many of these characterized attributes have direct relationships with the quality of the software system being produced. Empirical evidence is required to support the collection of measures for such metrics; hence these metrics are used as early indicators of such important external quality attributes. This research compared the CK and Martin's package metric suites in order to characterize the package reusability level in object-oriented software. Comparing the package level of metrics suites as they measure an external software quality attribute is supposed to help a developer know which metric suite can be used to effectively predict the software quality attribute at package level. In this research two open source Java applications, namely; jEdit and BlueJ were used in the evaluation of two package metrics suites, and were compared empirically to predict the package reusability level. The metric measures were also used to compare the effectiveness of the metrics in these package metrics suites in evaluating the reusability at the package granularity level. Thereafter metric measures of each package were normalized to allow for the comparison of the package reusability level among packages within an application. The Bansiya reusability model equation was adapted as a reusability reference quality model in this research work. Correlation analysis was performed to help compare the metrics within package metrics suites. Through the ranking of the package reusability level, results show that the jEdit application has 30% of its packages ranked with a very high reusability level, thus conformed to the Pareto rule (80:20). This means that the jEdit application has packages that are more reusable than packages in the BlueJ application. Empirically, the Martin's package coupling metric C_e with an r value of 0.68, is ranked as having a positive strong correlation with R_L , and this has distinguished the Martin's package metrics suite as an effective predictor of package reusability level from the CK package metrics suite.

ABSTRAK

Pakej adalah unit yang menguruskan kod sumber dalam sistem berorientasikan objek yang besar. Metrik yang digunakan di peringkat butiran pakej kebanyakannya mempunyai ciri-ciri seperti kekompleksan, saiz, perpaduan dan gandingan. Kebanyakan karakter atribut ini mempunyai hubungan secara langsung dengan kualiti sistem perisian yang dihasilkan. Bukti empirikal diperlukan untuk menyokong koleksi pengukuran metrik tersebut, dan oleh sebab itu metrik ini digunakan sebagai penunjuk awal sifat-sifat penting kualiti luaran. Kajian ini membandingkan metrik suite pakej CK dan metrik suite pakej Martin untuk menilai tahap guna semula pakej di dalam perisian berorientasikan objek. Melalui perbandingan tahap pakej metrik suite yang mengukur sifat luar kualiti perisian sepatutnya dapat membantu pembangun untuk mengetahui metrik suite yang mana yang boleh digunakan dengan berkesan dalam meramal sifat kualiti perisian di peringkat pakej. Dalam penyelidikan ini, dua sumber terbuka aplikasi Java, iaitu jEdit dan BlueJ telah digunakan dalam penilaian dua pakej metrik suite, dan dibandingkan secara empirikal untuk meramal tahap boleh gunasemula pakej tersebut. Selain itu, pengukuran metrik telah digunakan untuk membandingkan keberkesanan metrik ini di dalam pakej metrik suite, bagi menilai tahap boleh gunasemula di peringkat pakej butiran. Selepas itu, langkah-langkah pengukuran metrik setiap pakej telah dinormalkan bagi membolehkan perbandingan tahap boleh gunasemula pakej antara setiap pakej dalam setiap aplikasi. Persamaan model boleh gunasemula oleh Bansiya telah disesuaikan sebagai model kualiti rujukan boleh gunasemula dalam kerja-kerja penyelidikan ini. Analisis korelasi telah dijalankan bagi membantu membandingkan metrik dalam metrik pakej suite. Melalui kedudukan tahap boleh gunasemula pakej, keputusan menunjukkan bahawa aplikasi jEdit mempunyai 30% daripada pakejnya yang memiliki tahap boleh gunasemula yang sangat tinggi, mematuhi apa yang telah ditentukan dalam peraturan Pareto (80:20). Ini bermaksud bahawa aplikasi jEdit mempunyai pakej boleh gunasemula yang lebih tinggi berbanding pakej dalam aplikasi BlueJ. Secara empirikal, gandingan metrik C_e dengan nilai r dari 0.68 dalam pakej Martin telah dikelaskan sebagai mempunyai korelasi positif yang kukuh dengan R_L , dan ini membezakan metrik suite pakej Martin sebagai peramal tahap boleh gunasemula pakej yang berkesan dari metrik suite pakej CK.



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CHAPTER 1

INTRODUCTION

1.1 Research Overview

Software reuse is a process in which a new software application is built from existing software (Shiva and Shala, 2007). The concept is not new in programming and can be traced back to the advent of the concept of subroutines and functions. However, it came to be widely known during the NATO Software Engineering Conference in 1968 when it was formally proposed by Douglas McIlroy of Bell laboratories (Frakes and Kyo, 2005). Since then the concept has been bolstered by the tremendous growth in both software development and programming paradigms that support software reuse in principle.

Shiva and Shala (2007), reported that in software industry, corporations such AT&T, HP, Tata Consultancy Services (TCS) and many others have greatly embraced the concept of reusability in software development, due to the promises that the concept offers. The promises that software reuse offer include but not limited to; reduced software development cost, low maintenance and more so increased productivity on the part of the developer (Meena and O'Brien, 2011). Software reuse increases the productivity of the developer and can be of great help especially in an environment that software features become obsolete so fast like in the open source community.

Since consumers of such communities require new features very rapidly and bearing in mind that the consumer base is large, then features requested might tend to be enormous. Thus, when such features are effected on the current releases of a software product. Thus, a new product release is in inevitable (Wu, 2006). This is no surprise to the current state in software development, where it has becomes a known

fact that software constantly changes; since the business environment in which software operates in is also very dynamic in nature (Stephens and Rosenberg, 2007). As was foreseen by Lehman (1979), software should change to meet the requirements of a changing environment and hence realizing its potential too. Hence, software is said to evolve with changing needs in the operating business environment.

As software changes, its design structure also changes, this can happen either during the software development phase or at the maintenance phase. Structural changes may increase software complexity, which consequently hamper its external product properties such as understandability, maintainability and internally may also affect design properties such as reusability, modifiability and modularity (Vasa, 2010).

In addition, developers productivity need to be enhanced and software reusability is essential in this direction. This require a purposeful embracement of developing software that is reusable as its being developed. To accomplish that objective, it is important to have control of reusability as a design property and as software is being developed.

1.2 Research Background

Due to the way developers in open source environment handle software changes as they maintain and enhance features of current releases, it might not be easy to maintain a very sound structured design that can support some of the mentioned software quality attributes especially reusability (Brown and Booch, 2002). Reusability is said to have a very considerable effect on general software quality (Goel and Bhatia, 2013). Though software changes can be a bit challenging especially when there is a requirement such as maintaining good software quality on reusable software components. So too be able to achieve this, time and effort is required to always assess the quality of reusable components (Goel and Bhatia, 2013).

Assessing a software product quality attribute, require the reference to a quality model, which defines the properties that are to be measured in order to make a decision on the quality level of such an attribute. It is important to note that



software reusability as a software quality attribute was missing in ISO 9126 and as such was recently introduced into the ISO 25010 software quality model (ISO/IEC 25010, 2011). In ISO 25010, software reusability is one of the sub-characteristics of the external quality attribute maintainability, and therefore can only be measured using internal properties of the software product (ISO/IEC 25010, 2011). Since, it was missing even in the earlier ISO 9126 standard, researchers specified their own reusability assessment models including the one proposed by Poulin (1994), which are oftenly referred to as extended quality models (Thapar et al., 2014).

Using the extended quality models, various quality factors related to software reusability have been measured, which include: portability, flexibility, understandability, independence, stability and many others (Poulin, 1994), mostly assessing the reusability level of software products. In this section, a review of some of the related research in terms of assessment of software reusability is done and a summary of these related research studies are given in Table 1.1. This research work is concern with recent studies that have assessed software reusability in open source community.

Fazal et al. (2012), illustrate an evolutionary case study to evaluate a proposed conceptual reusability model which was used to study the reusability of software during evolution. An evaluation of the model was conducted using a case study, where two open source projects were used, to evaluate the metrics in the said reusability attribute model. Various releases of the said open source projects were evaluated, both at the class and method granularity levels using an assorted set of reusability metrics as per the proposed reusability attribute model. The model of proposed attribute reusability proposed various new metrics that were used in the assessment of software reusability. Except for the consideration of scale for the various metrics that were used in coming up with the new metrics, there is no mathematical rigour used to justify the coefficients of the various metrics in the equations of the new metrics.

Another research work done by Goel and Bhatia (2013), evaluated metrics in object-oriented software written in C++ based on three inheritance features with an objective of finding out which of these features have more impact on the software reusability. Inheritance features investigated include: multilevel, multiple and hierarchical inheritance; three C++ programs which had these features were used in this study. This study used Chidamber and Kemerer (CK) metrics suite in measuring



the inheritance features, later proposed new metrics for measuring the said inheritance features. However, the metrics were not validated, thus the researchers used their own intuition to suggest the aggregation of some of their metrics. From the original CK metrics and their derived metrics, it was found out that multi-level inheritance has more impact on reusability among the three features corroborating the principle of multi-level inheritance as a good indicator for reusability.

Ampatzoglou et al. (2011), did an empirical investigation on the reusability of design patterns and packages in open source projects, in order to help developers have a starting point in white box software reuse. The main concern in that research work was to characterize the reusability of these projects, identify reusable design patterns and packages that can be of help to developers that require to use them in other projects. The research work only investigated one release of each software project that was studied, and the granularity level was at package and design pattern level. Design level metrics from the Quality Model for Object Oriented Design (QMOOD) were used in characterising the reusability level of the software investigated in the study.

Another related research study is by Makkar et al. (2012), specified an inheritance metric that is better than Depth of Inheritance (DIT) or Depth of Inheritance of Class (DITC), with a reusability perspective, with the claim that current inheritance metrics are primitive and only give rough estimate of the inheritance of a class or lack validation support. The metric is theoretically validated through Weyuker's nine axioms, showing a good coverage of the inheritance concept in a class. Though, the metric might be good in terms of its rigour in validation and its measurement, it only covers one aspect of reusability, therefore other metrics need to be identified and used to accomplish the assessment of reusability as a whole.

A few of the research studies discussed this section considered investigating software reusability as software evolves and more, so all are not identify the corresponding software components which can be reused based on the software projects that were studied as shown in Table 1.1. Moreover, they are lacking in decision to advice the developers mentioned at their projects ways of how to reuse the software components present in their projects, so that they can increase productivity as they come up with new releases



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Table 1. 1: Assessment of Software Reusability

Authors	Case Study	No. of Projects	Granularity Level	Quality Model	Evolution
(Fazal et al., 2012)	Java Open Source Projects	2 (Jasmin, pBeans) 6 versions and 10 versions	Class, method	Proposed a quality model with new metrics proposed	Yes
(Goel and Bhatia, 2013)	C++ programs	3 programs (3 classes)	Class	CK metrics used, new metrics were also proposed	No
(Ampatzoglou et al., 2011)	Java Open Source Projects	29 projects	Design Patterns, packages	QMOOD (Design level metrics)	No
(Makkar et al., 2012)	Reusability Metric specification	No project	Class	DIT, DITC	No

Moreover, from the summary of the research studies as presented in Table 1.1, it is evident that different studies have touched a different granularity levels when it comes to reuse component. The class has been the most consistent granularity level used in most studies discussed, so this can largely be attributed to the metrics used. One other hand, aspect that was observed in many studies has appeared with a proposal of new reusability metrics, through the mathematical rigour required to validate them if they were lacking in serious way.

1.3 Problem Statement

Comparing package level metrics suites "as they measure an external software quality attribute" is supposed to help a developers to know which metric suite can be used to effectively predict the software quality attribute at package level. Nonetheless, software changes that are implemented due to addition feature and maintenance, that affect at the internal structures of the software, hence directly affecting design properties such as reusability, modularity and modifiability.

This research work, would like to compare two package level metrics suites on the design property, reusability. The purpose is to understand which of the two suites can effectively predict the reusability level of packages within an object-oriented software. The two package level metrics suites that were used to compare

package reusability level, were; the Martin's metrics suite and the CK metrics suite. The reusability computation index equation by (Bansiya, 2002) was adapted as the reusability quality model in this research work.

1.4 Research Aim and Objectives

The aim of this study is therefore to compare two package level metrics suites on the design property and reusability; in order to understand which of the two suites can effectively predict the reusability level of packages within object-oriented software. The aim of this study was achieved through the following objectives:

- i. Measure package reusability properties in two open source Java software using CK package metrics suite.
- ii. Measure the package reusability properties in two open source Java software using Martins package metrics suite.
- iii. Evaluate and compare package reusability level within the two open source Java software.
- iv. Evaluate the effectiveness of the two package metric suites in measuring package reusability level.

1.5 Scope of the Study

Some open-source software undergo a tremendous changes within a very short time, because of the environment they operate under; this puts a lot of constraint to the community developers, especially when coming up with new releases. Therefore, if the developers can be helped in terms of knowing which parts of their software can easily be reused; it can go a great length in reducing the development time of new features as requested by users.

This research would like to fill-in such a gap by first being able to characterize the reusability levels of packages in a mature open-source object-oriented software using two well-known package metrics suites. Two open source object-oriented software namely jEdit and BlueJ written in Java were used; the two open source projects were considered in this research since the two are from the same problem domain as Java programming editors. Three measurement tools,

namely; Metrics 1.3.8, JHawk and JDepend were used together with one reverse engineering tool called ObjectAid; all these tools were used as plug-ins in the Eclipse Java IDE. This measurement activity will help the developers to know the reusability of the packages in question, to help control deterioration of its structure in future changes. The object-oriented granularity level of concern in this research is the pegged at the package level, this is because the class is a very low level element for consideration in terms of reuse. The two metrics suite that were used are; Martin's (2006) package metrics suite and CK (1991; 1994) package metrics suite.

A comparison of the measurements from the reusability properties was done to know which of the two metric suites could effectively predict package reusability in an object-oriented software. These measurements can be used to allow the developers to know which package are more reusable than the others in terms of the metrics values. As an indicator, this will go a long way to control the design properties, because each package was evaluated on at least a minimum of three measures, letting the developer understands the packages structural elements, such as coupling, cohesion and its interface size. The comparison of the metrics from the two metrics suites was done using correlation analysis which using the measures of reusability properties obtained from two open Java source software.

1.6 Significance of the Study

Measuring a software product is essential in software engineering for commonly two purposes as described by Fenton (Fenton and Bieman, 2015); first, to understand the level of the quality attribute in the product, secondly to be able to control it as its being developed. This study will first help the developer to address basic issues that is essential to reusability, such as: understanding the package reusability level in the software product as it is being developed; ultimately then know which of the packages are likely to be more reusable than the others. It will also help the developer to know which of the two package metric suites is more effective in predicting package reusability in object-oriented software. These are some of the concerns that this research tried to handle through the results obtained from measuring the reusability level of two open source case study, namely; jEdit and BlueJ using the two package metrics suites.

Measurement in a software product is an indicator of an attribute quality level within a software product, which sends a signal to the developer that the software product is moving towards the right direction in terms of the specified design goals or not. In this research the package reusability level was measured to ascertain its level in the software product, hence go a long way to help the developer to understand the reusability level of each package in two open source Java software. This will go a long way in guiding the design of the software product being developed and let the developer reuse such packages in developing other software products in the same domain. The two package reusability measures will also help to characterize the structural design properties of the software by measuring the cohesion and coupling among packages, before computing the reusability level of the package. Through the consistency of the metric values from each metric suite the developer will be able to know which of the two metrics suites can effectively predict the reusability level.

1.7 Chapter Summary

This chapter was able to introduce the concept of reusability from a measurement point of view and its relationship to software evolution, this was covered in Section 1.1. In Section 1.2, a brief overview of the related work that of concern, that show the missing link in literature was discussed to help the researcher map the scope of this research work. That was followed immediately by a description of the problem statement in Section 1.3, whose objectives were specified in Section 1.4. After which, the scope of the research work was specified in the Section 1.5. In Section 1.6, a justification of the study was fully discussed.



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A common phenomenon among software development houses is that, the process of software development is always faced with issues in terms of cost, not meeting delivery time, delivery of software that does not fully meet user's functionality or has runtime errors among other issues (Nazareth and Rothenberger, 2004). Software reuse has been recognized by many researchers (Tripathy and Naik, 2014; Keswani et al., 2014; Spoelstra et al., 2011; Agresti, 2011) as a way that can help to solve some of the software crisis issues mentioned; especially when the software's evolution rate is a bit faster.

User's needs always increase continuously, and to accommodate those needs the softwares should also change. It is therefore necessary for developers to craft software that is flexible enough, which can accommodate change when required, afford extendibility with or without rework. Such a description fits so well to the characteristics of software product property called software reusability. Most software systems that have exhibited some success in the market, should be able to add new system capabilities when required - that is as it evolves; this can be possible if software modules written earlier can be reused (Stierna and Rowe, 2003). Hence, software evolution and software reusability are related in one way or another; software that is reusable can easily evolve as user needs or change in requirements.

As software evolves then the developer needs to also be careful on how its internal properties also change to be able to facilitate later reuse of some software artefacts. Thus, it is essential for the developer to understand and control the level of some internal product attributes such as reusability, modularity, modifiability among



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others; which have a direct effect on external product properties. To be able to characterize and hence control the reusability level as software evolves, reusability level measurement is required for each software release as it evolves.

The need for the software measurement in order to characterize and control a software product attribute, specifically for reusability was briefly discussed in sub section 1.2. That section also gave an overview of the existing research that has been conducted in the field of software reusability, which was then be further expounded in this sub section 2.3 and 2.4. To achieve the objectives stated in sub section 1.4, a package reusability metrics are required; these are discussed in details sub section 2.3.1. Before that discussion, a detailed coverage of what software reusability entails is first done in the Section 2.2 that follow.

2.2 Software Reusability

Software reusability is a software product property that specifies the ability of a software artefact to be reused in developing new software (ISO/IEC 25010, 2011). This property hangs on the process of software reuse, which involves crafting new software systems by using already existing software artifacts instead of developing them from scratch (De' and Rao, 2013; Heinemann et al., 2011; Lucrédio et al., 2008). In most large software systems, it is always possible to find reuse opportunities, this can be confirmed by the facts given by Nazareth and Rothenberger (2004), that suggested about 75% of functions within a program can be reused in other programs. That fact is also confirmed what was suggested by Joyce (1990), that roughly about 15% of all source code is unique; meaning the other code can be easily reused in other contexts. Thus, in most software systems, that are large enough, there should be software artifacts that can be reused either within that system or externally.

The estimates suggested here are mostly based on software systems that are similar, which in most cases will be from similar application domains, also may be from a specific software systems domain or are using similar programming languages (Nazareth and Rothenberger, 2004; Sommerville and Kotonya, 1998). There are many examples of software reuse in practice, stemming from as easy as functions as well as subroutines, where a repetitive task is put together in a sub program, then called when required; though not a common example. Other examples

include libraries or packages, application programming interfaces (API), frameworks, design patterns among other examples (Sojer and Henkel, 2011; Sommerville, 2010; Postmus and Meijler, 2008; Brown and Booch, 2002). In Section 2.2.3, a detailed classification of the software reuse is done, and in each case examples are provided.

The open source community, has provided an avenue for software reuse as acknowledged by Brown and Booch (2002), libraries, APIs, frameworks and many others have been provided with access to the source code also; making it easier for developers to directly reuse or rework some solutions to suit their needs. In the open source community, frameworks and libraries for many recurring tasks are provided for in software repositories such as Source Forge, Linux, Apache and many others (Sojer, 2011; Brown and Booch, 2002). Examples of popular frameworks that have been used in market with tremendous impact include web application frameworks like Apache, Ant, Hibernate, Struts; programming platforms like Eclipse, Netscape among others (Heinemann et al., 2011). The contribution of these frameworks and libraries have touched many software development and some may not be able to survive without such software in use. Open source software is driven towards reuse, since they have to keep up with the rapid pace of dynamic change in user requirements and effecting new user requirements (Brown and Booch, 2002). In as much as these repositories are good, they tend to be abused in terms of software reuse.

With the advent of the many online code repositories offering access to source code, some software developers who copy and paste such code into their software systems may perceive that as software reuse (Barzilay and Urquhart, 2014). While this process make the developer not reinvent the wheel as it were, it is a process of copying and pasting, which culminates to code duplication, leading to bad code seems as described by Fowler et al. (1999). As good as it is to the developer at the time of doing it, it should not be confused with software reuse; it is code duplication. As the access to such repositories is there, source code reuse should be in form of the impacts that are modular in form such as libraries, packages among others. Such modular impacts when required in development, can then be used in that form or reworked but not copied. This is one of many issues which faced in case of software reuse, many examples are given in sub section 2.2.2; before then a discussion of the need for reuse and its advantages is done in sub section 2.2.1.



2.2.1 Software Reuse

Software reuse has been widely accepted, has seen a lot of progress made in the software industry, in relation to reducing the issues that are always associated with the phenomena of software crisis. In literature, reusing already existing code has a lot of benefits that include:

i. Increased Productivity

The use of already existing software artifacts increase the productivity of software developers, since new products are not written from scratch and can therefore use their time to write that part of the software that really is unique (Rothenberger et al., 2003; Lim, 1994). This in a way expedites the creation of a new software product, hence reduces the time to develop and considerable reduces the cost of the software produced (Meena and O'Brien, 2011). This is a very important reuse benefit since one of the issues that software development is battling out in practice is increasing production of software and ultimately reducing the cost of the product. This was one of the concerns of McIlroy and his colleagues, in their seminal work (McIlroy et al., 1968) on software reuse coined the concept software factory in 1968.

ii. Improved Software Quality

An existing software impacts that can be reused presents a tested piece of software, hence when reused assures that the product realized will also conform to the quality level of the impacts (Barzilay and Urquhart, 2014; Lim, 1994). As said earlier, the part of software that is unique is always relatively small compared to the parts that are reused, hence if a software product is built from existing software artifacts the end product will be of high quality (Meena and O'Brien, 2011). Again this property considerably reduces the quality issues that of concern in software development, since reusable artifacts have a proven quality level.



iii. Enhanced Code and Design Standards

Using existing frameworks, present a proven system architecture that the developer should conform to, hence in a way will push the developer to conform to a coding and design standard that is with reference to the framework being used (Heinemann et al., 2011; Brown and Booch, 2002). Making it clear that developers that are using the similar frameworks will follow a certain way of reasoning in terms of coding and design standards. Hence, developers within such domain of frameworks can easily share reusable software artifacts and to some extent follow all design principles within that domain.

iv. Facilitates Knowledge Reuse

Software reuse is one way of sharing software development knowledge amongst developers (Sojer, 2011). This was further enhanced by introduction of design patterns (Gamma et al., 1994) which involves expert developers sharing their expert experience with novice designers through patterns. Through frameworks some design patterns are now part of developer's toolkit and it is a must in one way or the other to follow these design patterns to fully utilize the framework.

The four purposes which also be viewed as benefits of software reuse are not an exhaustive list but form a basis of almost all other objectives or reasons why software reuse is important to the software developer and software development house. It is obvious it is not all roses to software reuse, challenges of software reuse are presented in the next sub section.

2.2.2 Challenges of Software Reuse

Despite the benefits that can be accrued by reusing software artifacts, software reuse has still not reached its full potential due to many challenges it faces (Spoelstra et al., 2011). This is evident in any field that has a lot to accomplish in varying contexts of use, again the issue of it being a young concept and the complexity of the artifact that

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