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Towards a Software Metric for OSGi

Graduation Thesis

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“If I have seen farther than others,
it is because I stood on the shoulders of giants.”
— Sir Isaac Newton

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ABSTRACT

Todays software applications are becoming more complex, bigger, dynamic and harder to maintain. One way to overcome modern systems complexities is to build modular applications so we can divide it into small blocks which collaborate to solve bigger problems, the so called *divide to conquer*. Another important aspect in the software industry that helps building large applications is the concept of software quality because its well known that higher quality softwares are easier to maintain and evolve at long term.

The Open Services Gateway Initiative(OSGi) is the *de facto* standard for building Java modular applications but there is no automated way to measure the quality of OSGi systems. In the context of Java applications there are many well known quality metrics and tools to measure application's quality but when we move to Java modular applications where standard quality metrics does not fit or even exist, for example module dependency metrics, we run out of options.

In this work will be presented a tool called *Intrabundle* that analyses OSGi projects and measure their quality. Its also proposed 6 metrics based on good practices inside OSGi world which are applied to 10 real OSGi projects that vary in size, teams and domain.

Keywords: OSGi. java. quality. metrics. modularity. intrabundle.

RESUMO

As aplicações de software hoje em dia estão cada vez mais complexas, maiores, dinâmicas e mais difíceis de manter. Uma maneira de superar as complexidades dos sistemas modernos é através de aplicações modulares as quais são dividas em partes manores que colaboram entre si para resolver problemas maiores, o famoso *dividir para conquistar*. Outro aspecto importante na industria de software que ajuda à construir aplicações grandes é o conceito de qualidade de software já que é sabido que quanto maior a qualidade do software mais facil de mante-lo e evolui-lo a logo prazo será.

The Open Services Gateway Initiative(OSGi) é o *padrão de fato* para se criar aplicações modulares em java porém não existe forma automatizada de se medir a qualidade de sistemas OSGi. No ambito de aplicações java existem diversas metricas de qualidade e ferramentas para medir a qualidade de software mas quando entramos no contexto de aplicações modulares, onde as métricas conhecidas não se encaixam ou não existem, por exemplo dependência entre módulos, ficamos sem opções.

Neste trabalho será apresentada uma ferramenta chamada *Intrabundle* que analisa projetos OSGi a mede sua qualidade. Ainda seram propostas métricas de qualidade baseadas em boas práticas conhecidas do mundo OSGi que serão aplicadas em 10 projetos reais que variam em tamanho, equipes e domínio.

Palavras-chave: OSGi. java. quality. metrics. modularity. intrabundle.

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LIST OF ABBREVIATIONS AND ACRONYMS

CISQ Consortium for IT Software Quality

JVM Java Virtual Machine

IEC International Electrotechnical Commission

ISO International Organization for Standardization

1 INTRODUCTION

This chapter will drive the reader through the context and motivation of this work followed by the objectives and later the organization of this text is presented.

1.1 Context

One of the pillars of sustainable software development is its quality which can basically be defined as internal and external where the first focuses on how software meets its specification and works accordingly to its requirements and the second is aimed on how well the software is structured and designed. To measure external quality there is the need to execute the software[1] either by an end user accessing the system or an automated process like for example functional testing or performance testing. Internal quality however can be verified by either *statical analysis* that is mainly the inspection of the source code itself or by dynamic analysis which means executing the software like for example automated *whitebox testing*, the detailed investigation of internal logic and structure of the code (KHAN et al., 2012).

With good software quality in mind we take applications to another level where maintainability is increased, correctness is enhanced, defects are identified in early development stages, which can lead up to 100 times reduced costs (BEOHM et al., 2001), and also other characteristics like reusability, reliability and portability are benefited by higher software quality.

A well known and successful way to structure software architecture is to modularize its components allowing easier evolution of the system because smaller modules are typically easier to maintain than monolith applications. In the Java ecosystem although there is a moving to modularize the JDK and Java applications with the project Jigsaw (KRILL, P.) and also the recent *microservices* movement (KNORR, E.). Today the only practical working and well known solution for modular Java applications is OSGi, a very popular component-based and service-oriented framework for building Java modular applications which is the *de facto* standard solution for this kind of software since early 2000's and have being used as basis of most JavaEE application servers, the open source IDE Eclipse, Atlassian Jira and Confluence to cite a few big players using OSGi.

In the context of Java modular applications using OSGi and software quality there is no known standard way neither tools to measure OSGi projects *internal quality* (**?**) although for *external quality* the classical approaches like automated testing are sufficient and widely used.

1.2 Objectives

The main objective of this work is to create software metrics to measure internal quality of OSGi based projects where this metrics must reflect good practices in the OSGi world. The

[1] Also known as dynamic analysis

main difference the proposed metrics have compared to classical software metrics is that the first will be based on modularity attributes that only exists in modular applications.

Another aim of this work is to create a tool to apply and validate the metrics on real OSGi projects and finally analyze the resulting qualities produced by the tool.

1.3 Organization

This text is organized in the following way. First chapter defines the context, motivation and objectives of this work. The second chapter will introduce the main concepts and technologies used in this work and will be divided into two main sections where the first will be focused in the area of software quality like quality measurement, quality metrics, program analysis and quality analysis tools and the second section of chapter two will present Java and OSGi, how standard Java and OSGi are different in respect to quality metrics and why we need different metrics for OSGi. The third chapter presents **Intrabundle**, an OSGi code introspection tool to measure internal quality, we will see how Intrabundle works, what kind of information it extracts and what metrics it is applying. The fourth chapter will analyze the results Intrabundle produces and validate them to decide if this work has a valid contribution or not. The last chapter will present the conclusions and future work on this subject.

2 STATE OF ART

This chapter presents an overview of the concepts and technologies that were studied and used on the development of this work. In section *2.1 - Software Quality*, will be presented general aspects of software quality such as *quality measurement*, *software metrics*, *program analysis* and some tools that are used in this area.

Section *2.2 - Java and OSGi* will introduce OSGi a framework for build service oriented Java modular applications as well the motivation behind this solution and why standard quality metrics aren't sufficient for this kind of application.

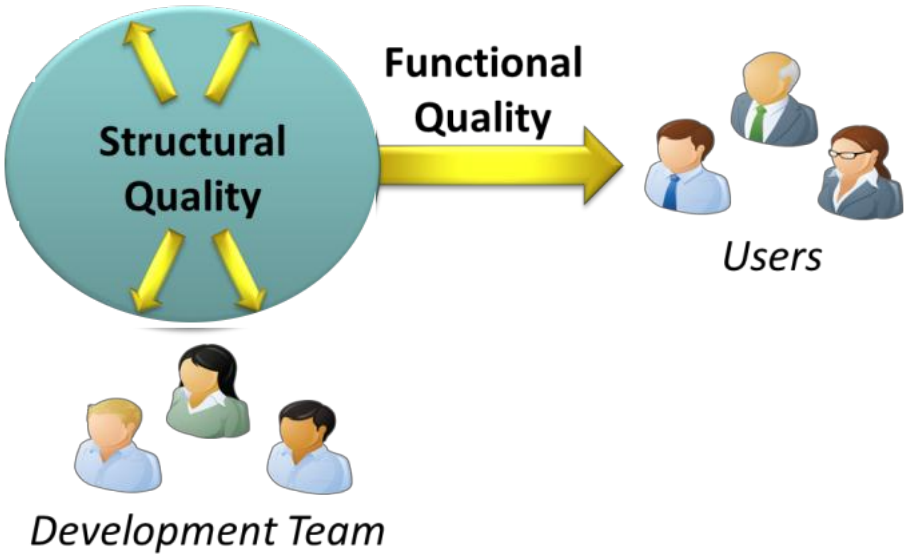
2.1 Software Quality

There has been many definitions of software quality(TODO REF - Metrics and Models in Software Quality Engineering) and there is even an ISO norm for it, the ISO/IEC 25010 (ISO25010, 2011). All this definitions agree that the main motivation to perform continuous software quality management is to avoid **software failures** and increase **maintainability** in the sense that the more quality a program has the easier will be to maintain, the less bugs or abnormal behavior it will have and the more it will conform with its functional and non functional requirements[1].

Another important aspect of software quality is that it can be divided in two groups, the **external** and **internal** quality. When we talk about *external quality* we are aiming to the user view which is the one that sees the software working and use it, this kind of quality is usually enforced through software testing. External quality can also be mapped to functional requirements so the greater external quality is the more usable and less defects it will have for example. The opposite is internal or structural quality that aims to how the software is architect-ed internally which is the perspective of the programmer and non functional requirements so the higher internal quality the better the code is structured, efficient, robust and maintainable it should be. Image 2.1 illustrates internal and external quality and its target audience.

[1]Functional and non functional requirements can be simply defined as *what* the software does and *how* the software will do respectively

Figure 2.1: Internal and external quality audience



2.1.1 Quality Measurement

Quality measurement focuses on quantifying software desirable characteristics and each characteristic can have a set of measurable attributes, for example *high cohesion* is a desirable characteristic and *LOC - lines of code* is a measurable attribute related to cohesion. Quality measurement is close related to internal quality and in most cases is performed via static code analysis where program code is inspected to search for quality attributes to be measured but in some cases a dynamic analysis, where the program analysis is done during software execution, can be performed to measure characteristics that can be perceived only when software is running, for example performance or code coverage[2].

In the extent of this work the characteristics of software to be considered and measured later are listed and described in table 2.1:

[2] A technique that measures the code lines that are executed for a given set of software tests, its also considered a software metric.

Table 2.1: Quality characteristics to be considered

Characteristic	Description	OSGi example
Reliability	the degree to which a system or component performs its required functions under stated conditions for a specified period of time.	Bundles should not have stale service references.
Performance Efficiency	Performance relative to the amount of resources used under stated conditions for a specified period of time.	Bundle startup time, also bundle dependency can decrease performance.
Security	the degree of protection of information and data so that unauthorized persons or systems cannot read, access or modify them.	Bundles should declare permissions
Maintainability	The degree to which the product can be modified.	Modules should be loosely coupled, bundles should publish only interfaces etc.

Source: CISQ (2013)

2.1.2 Software Metrics

A software metric is the measurement of a software attribute which in turn is a quantitative calculation of a characteristic. Software metrics can be classified into three categories: product metrics[3], process metrics[4], and project metrics[5]. Software quality metrics are a subset of software metrics that focus on the quality aspects of the product, process, and project.(KAN, 2002).

2.1.2.1 Good Software Metrics

Good metrics may have the following aspects:

- *Linear*: metric values should follow an intuitive way to compare its values like for example higher values should correspond to better quality whereas lower values to worse quality and vice versa.
- *Independent*: two metric values should not interfere on each other.
- *Repeatable*: this is a very important aspect in continuous quality management where software is changing all the time and we want to measure quality on every change.
- *Accurate*: the metric should be meaningful and should help answer how good a software

[3]Product metrics describe the characteristics of the product such as size, complexity, design features, performance

[4]Process metrics can be used to improve software development and maintenance.Examples include the effectiveness of defect removal during development and response time of bug fixing

[5]Project metrics describe the project characteristics and execution. Examples include the number of software developers, cost, schedule, and productivity

attribute is, for example using latency[6] to calculate response time[7] in a web application isn't accurate.

2.1.2.2 Common Software Metrics

The table 2.2 below shows some well known software metrics and its description:

Table 2.2: Common Software metrics

Metric	Description
Cyclomatic complexity	It is a quantitative measure of the complexity of programming instructions.
Cohesion	measure the dependency between units of code like for example classes in object oriented programing or modules in modular programming like OSGi.
Coupling	measures how well two software components are data related or how dependent they are.
Lines of code (LOC)	used to measure the size of a computer program by counting the number of lines in the text of the program's source code.
Code coverage	measures the code lines that are executed for a given set of software tests
Function point analysis (FPA)	used to measure the size (functions) of software.

Source: SQA (2012)

2.1.3 Program Analysis

Program analysis is the process of automatically analyzing the behavior of computer programs. Two main approaches in program analysis are **static program analysis** and **dynamic program analysis**. Main applications of program analysis are program correctness, program optimization and quality measurement.

2.1.3.1 Static Program Analysis

Is the analysis of computer software that is performed without actually executing programs (Wichmann et al., 1995). In this kind of analysis source code is inspected and valuable information is collected based on its internal structure and components.

[6]The delay incurred in communicating a message, the time the message spends "on the wire"
[7]The total time it takes from when a user makes a request until they receive a response

2.1.3.2 Dynamic Program Analysis

Is a technique that analyze the system's behavior on the fly, while it is executing. The main objectives of this kind of analyze is to catch *memory leaks*[8], identify arithmetic errors and extract code coverage.

2.1.4 Quality Analysis Tools

The table 2.3 lists some code quality analysis tools in the Java ecosystem:

Table 2.3: Quality analysis tools

Name	Description	Type
SonarQube	An open source platform for continuous inspection of code quality.	static
FindBugs	An open-source static bytecode analyzer for Java.	static
Checkstyle	A static code analysis tool used in software development for checking if Java source code complies with coding rules.	static
PMD	A static ruleset based Java source code analyzer that identifies potential problems.	static
ThreadSafe	A static analysis tool for Java focused on finding concurrency bugs.	static
InFusion	Full control of architecture and design quality.	static
JProfiler	helps you resolve performance bottlenecks, pin down memory leaks and understand threading issues	dynamic
JaCoCo	A free code coverage library for Java.	dynamic
Javamelody	Java or Java EE application Monitoring in QA and production environments.	dynamic
Introscope	An application management solution that helps enterprises keep their mission-critical applications high-performing and available 24x7.	dynamic

Figure 2.2 shows the execution of static analysis on *Intrabundle* using **PMD**, note that PMD is based on rules and Intrabundle break some of them(intentionally) like **Unused variables**, **EmptyCatchBlock** so PMD consider them compile failure and the project cannot be compiled until the rules are fixed in code:

[8]Resources that are hold on system's memory and aren't released

Figure 2.2: Intrabundle PMD rule violation

```
[INFO] >>> maven-pmd-plugin:3.2:check (default) @ intrabundle >>>
[INFO]
[INFO] --- maven-pmd-plugin:3.2:pmd (pmd) @ intrabundle ---
[INFO]
[INFO] <<< maven-pmd-plugin:3.2:check (default) @ intrabundle <<<
[INFO]
[INFO] --- maven-pmd-plugin:3.2:check (default) @ intrabundle ---
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.metric.DefaultMetricsCalculator:119 Rule:EmptyCatchBlock Priority:2 Must handle exceptions.
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.model.ManifestMetadata:143 Rule:StringInstantiation Priority:2 Avoid instantiating String objects; this is u
sually unnecessary..
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.model.ManifestMetadata:160 Rule:UseIndexOfChar Priority:3 String.indexOf(char) is faster than String.indexOf
(String)..
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.model.ManifestMetadata:162 Rule:UseIndexOfChar Priority:3 String.indexOf(char) is faster than String.indexOf
(String)..
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.model.ManifestMetadata:201 Rule:UseIndexOfChar Priority:3 String.indexOf(char) is faster than String.indexOf
(String)..
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.model.ManifestMetadata:255 Rule:UseIndexOfChar Priority:3 String.indexOf(char) is faster than String.indexOf
(String)..
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.model.ManifestMetadata:309 Rule:UseIndexOfChar Priority:3 String.indexOf(char) is faster than String.indexOf
(String)..
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.model.OSGiModuleImpl:186 Rule:EmptyCatchBlock Priority:2 Must handle exceptions.
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.model.OSGiProjectImpl:37 Rule:UnusedPrivateField Priority:3 Avoid unused private fields such as 'projectMetr
ic'..
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.model.OSGiProjectImpl:38 Rule:UnusedPrivateField Priority:3 Avoid unused private fields such as 'metrics'..
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.plugin.BundlePlugin:22 Rule:UnusedPrivateField Priority:3 Avoid unused private fields such as 'prompt'..
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.plugin.LocalePlugin:34 Rule:UnusedPrivateField Priority:3 Avoid unused private fields such as 'event'..
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.plugin.OSGiScanPlugin:39 Rule:UnusedPrivateField Priority:3 Avoid unused private fields such as 'moduleLevel
s'..
[INFO] PMD Failure: br.ufrgs.rmpestano.intrabundle.util.ProjectUtils:328 Rule:UnusedLocalVariable Priority:3 Avoid unused local variables such as 'line'..
[INFO] ------------------------------------------------------------------------
[INFO] BUILD FAILURE
```

The rules are totally customizable via xml configuration, Intrabundle PMD rules are shown in Figure 2.3:

Figure 2.3: Intrabunde PMD ruleset

```xml
<?xml version="1.0"?>
<ruleset name="Custom ruleset" xmlns="http://pmd.sourceforge.net/ruleset/2.0.0"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://pmd.sourceforge.net/ruleset/2.0.0">
    <description>
        This ruleset checks my code for bad stuff
    </description>

    <exclude-pattern>.*/src/test/.*</exclude-pattern>

    <!-- Here's some rules we'll specify one at a time -->
    <rule ref="rulesets/java/unusedcode.xml/UnusedLocalVariable" />
    <rule ref="rulesets/java/unusedcode.xml/UnusedPrivateField" />
    <rule ref="rulesets/java/imports.xml/DuplicateImports" />
    <rule ref="rulesets/java/basic.xml/UnnecessaryConversionTemporary" />

    <rule ref="rulesets/java/strings.xml">
        <exclude name="AvoidDuplicateLiterals" />
        <exclude name="AppendCharacterWithChar" />
        <exclude name="ConsecutiveLiteralAppends" />
        <exclude name="InefficientStringBuffering" />
    </rule>

    <!-- We want to customize this rule a bit, change the message and raise
        the priority -->
    <rule ref="rulesets/java/basic.xml/EmptyCatchBlock" message="Must handle exceptions">
        <priority>2</priority>
    </rule>

    <!-- Now we'll customize a rule's property value -->
    <rule ref="rulesets/java/codesize.xml/CyclomaticComplexity">
```

Source: intrabundle ruleset (2014)

2.2 Java and OSGi

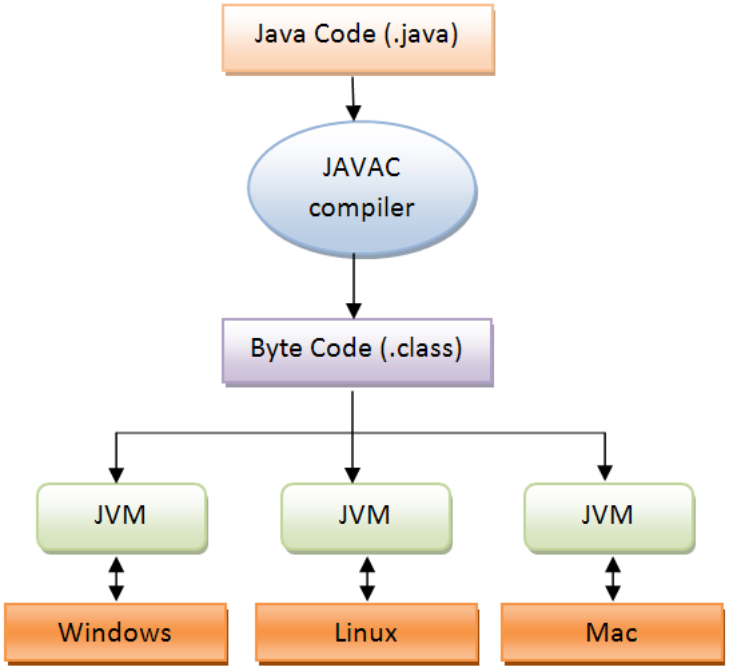
In the context of Java™ programming language (Arnold et al., 2005), which accordingly to IEEE spectrum of this year is the most popular programming language (IEEE Spectrum, 2014),

and modular applications[9] this section will introduce the Java language and OSGi framework.

2.2.1 The Java language

Java is a general purpose object oriented[10] programming language created by Sun Microsystems in 1995 which aims on simplicity, readability and universality. Java runs on top of the so called JVM, the acronym for Java Virtual Machine, which is a abstract computing machine[11] and platform-independent execution environment that execute Java byte code[12]. The JVM converts java byte code into host machine language(e.g. linux, windows etc...) allowing Java programs to "run everywhere" independently of operating system or platform. JVM implementations are different for each platform but the generated bytecode is the same, Figure 2.4 illustrates how JVM works:

Figure 2.4: JVM architecture



Other aspects of Java are listed below:

- Type safe[13]
- Dynamic: during the execution of a program, Java can dynamically load classes
- Strong memory management(no explicit pointer)

[9] A software design technique that emphasizes separating the functionality of a program into independent, interchangeable modules which represent a separation of concerns and improves maintainability

[10] Object-oriented programming(OOP) integrates code and data using the concept of an "object" which is a piece of software that holds state and behavior

[11] Also known as *Virtual Machine* which is an emulation of a particular computer system

[12] The intermediate output of the compilation of a program written in Java that can be read by the JVM

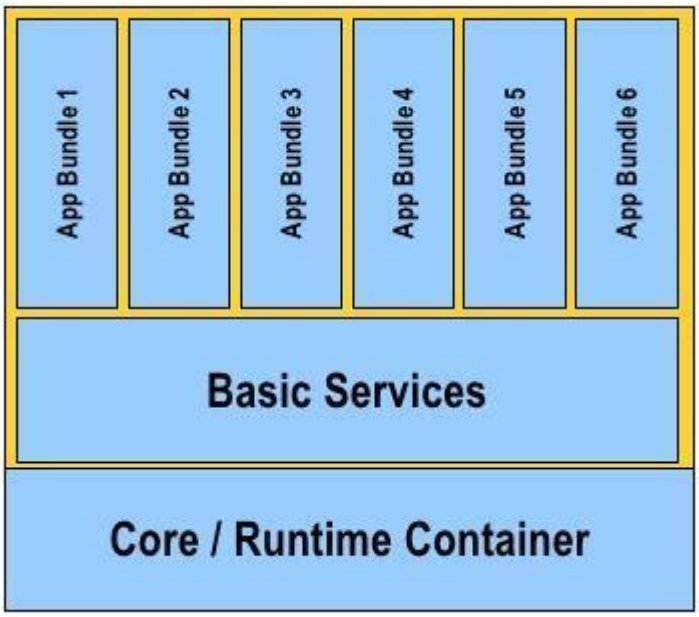
[13] Type safety is the extent to which a programming language discourages or prevents type errors

- Automatic garbage collection to release unused objects from memory
- Robust: extensive compile-time checking so bugs can be found early
- Multithreaded[14]
- Distributed: networking capability is inherently integrated into Java

2.2.2 The OSGi service platform

OSGi is a component based service oriented platform specification maintained by *OSGi Alliance*[15]. As of November 2014 the specification is at version 6 and currently has four implementations[16]. It is composed by *OSGi framework* and *OSGi standard services*. The framework is the runtime that provides the basis of all OSGi module system functionalities like modules management for example and standard services define some reusable apis and extension points to easy development of OSGi based applications. Figure 2.5 illustrates OSGi platform architecture:

Figure 2.5: OSGi architecture



2.2.2.1 Bundles

Bundles are the building blocks of OSGi applications. A bundle[17] is a group of Java classes and resources packed as .jar extension with additional metadata in manifest MANIFEST.MF file

[14] Multithreading is a program's capability to perform several tasks simultaneously
[15] A non profit worldwide consortium of technology innovators
[16] Apache Felix, Eclipse Equinox, Knopflerfish and ProSyst
[17] Also known as module

describing its module boundaries like for example the packages it imports and exports. Below is an OSGi manifest file example:

```
Bundle-Name: Hello World
Bundle-SymbolicName: org.wikipedia.helloworld
Bundle-Description: A Hello World bundle
Bundle-ManifestVersion: 2
Bundle-Version: 1.0.0
Bundle-Activator: org.wikipedia.Activator
Export-Package: org.wikipedia.helloworld;version="1.0.0"
Import-Package: org.acme.api;version="1.1.0"
```

Looking at manifest OSGi can ensure its most important aspect, *modularity*, so for example our **Hello World** bundle will only be started(later we will explore bundle lifecycle) if and only if there is a bundle (in resolved or installed state) that exports *org.acme.api* package, this is called **explicit boundaries**.

With OSGi, you modularize applications into bundles. Each bundle is a tightly coupled, dynamically loadable collection of classes, JARs, and configuration files that explicitly declare any external dependencies. All these characteristics are provided in OSGi by three conceptual layers that will be briefly presented here, *Module*, *Service* and *Lifecycle*.

2.2.2.2 Module layer

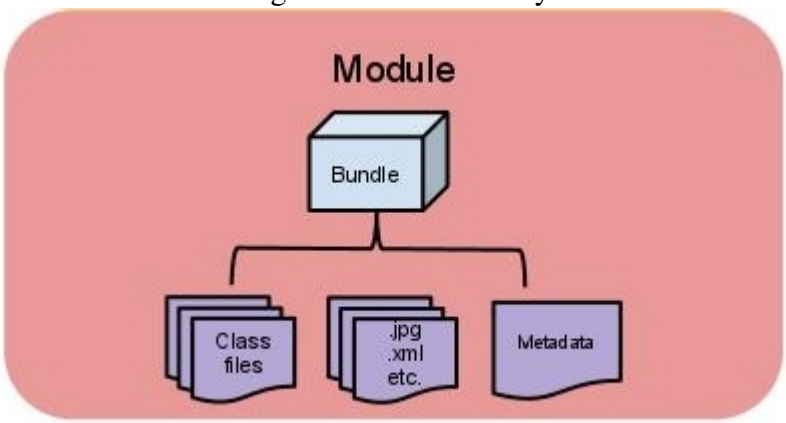
This layer is the basis for others as modularization is the key concept of OSGi. The module layer defines OSGi module concept - bundle, which is a JAR file with extra metadata. It also handles the packaging and sharing of Java packages between bundles and the hiding of packages from other bundles. The OSGi framework dynamically resolves dependencies among bundles and performs bundle resolution to match imported and exported packages. This layer ensures that class loading happens in a consistent and predictable way.

2.2.2.3 Lifecycle layer

Provides access to the underlying OSGi framework through the *Bundle Context* object. This layer handles the lifecycle of individual bundles so you can manage your application dynamically, including starting and stopping bundles to manage and evolve bundles over time. Bundles can be dynamically installed, started, updated, stopped and uninstalled. Figure 2.7 shows bundle lifecycle and its possible states where transitions are performed by OSGi commands like *start* or *stop* for example and states are represented in squares:

If OSGi were a car, module layer would provide modules such as tire, seat, etc, and the lifecycle layer would provide electrical wiring which makes the car run.

Figure 2.6: Module Layer



Source: conceptual layers (2011)

2.2.2.4 Service layer

This layer provides communication among modules and their contained components. Service providers publish services[18] to *service registry*, while service clients search the registry to find available services to use. The registry is accessible to all bundles so they can *publish* its services as well *consume* services from other bundles.

This is like a service-oriented architecture (SOA) which has been largely used in web services. Here OSGi services are local to a single VM, so it is sometimes called SOA in a VM.

2.2.3 Vanilla Java vs OSGi

The main motivation behind OSgi and advantage over standard Java application, as illustrated before, is the modularity. The main issue with Java default runtime is the way Java classes are loaded, it is the root cause that inhibits modularity in classical Java applications. In standard Java user classes[19] are loaded by a classloader[20] from the same classpath[21], also known as **flat classpath**. A flat classpath is the main cause of a well known problem in Java applications, the **Jar Hell**footnoteA term used to describe all the various ways in which the classloading process can end up not working. Figure 2.10 is an example of Jar hell where multiple JARs containing overlapping classes and/or packages are merged based on their order of appearance in the class path.

[18] A Service is an operation offered as an interface that stands alone in the model, without encapsulating state(Evans and Fowler, 2003)

[19] Classes that are defined by developers and third parties and that do not take advantage of the extension mechanism

[20] A class loader is an object that is responsible for loading classes

[21] classpath tells Java virtual machine where to look in the filesystem for files defining these classes

Figure 2.7: OSGi bundle Lifecycle

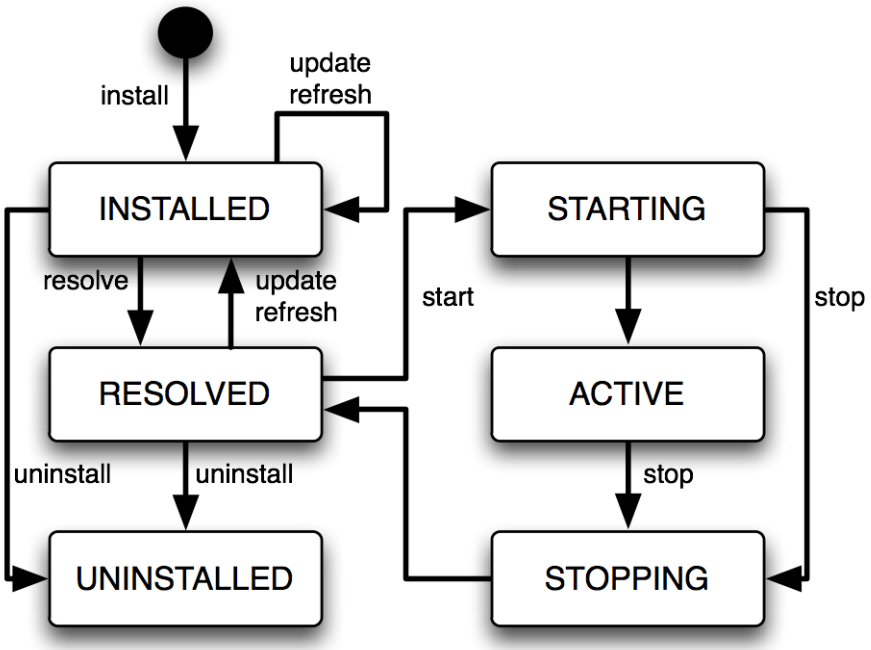
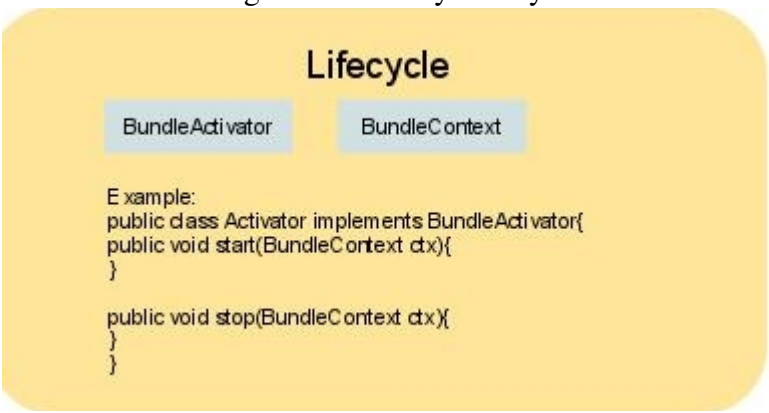


Figure 2.8: Lifecycle Layer



Source: conceptual layers (2011)

Figure 2.9: Service Layer

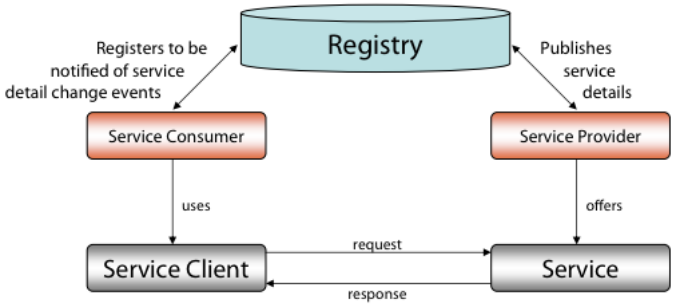
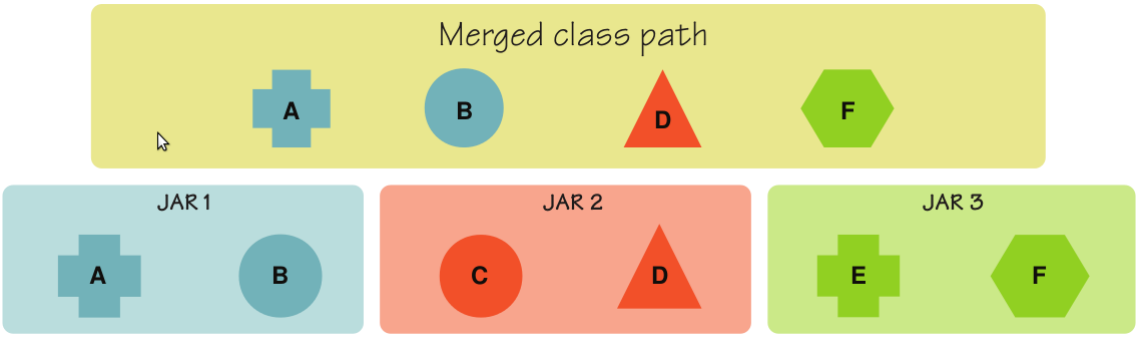


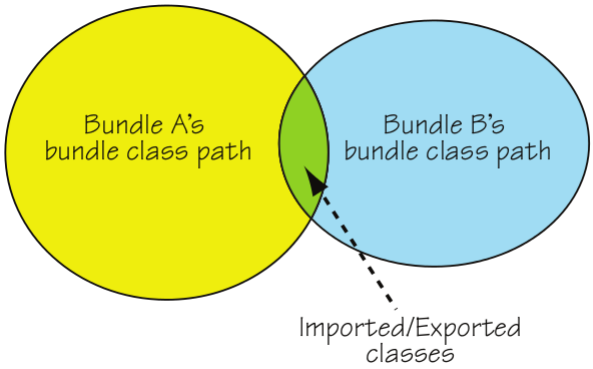
Figure 2.10: Java jar hell



Source: (HALL et al., 2011, p. 7)

In the OSGi environment instead of a *flat classpath* each bundle has its classloader and its classpath. See Figure 2.11where Bundle A's classpath is defined as the union of its bundle classpath with its imported packages, which selected for imported packages, that are provided by bundle B's exports.

Figure 2.11: Bundle classpath



Source: (HALL et al., 2011, p. 59)

We can say we have a graph of classpath that allows powerful versioning mechanisms so for example we can have multiple versions of the same class or resource loaded at the same time(used by different bundles) in OSGi runtime. This enables independent evolution of dependent artifacts which, in the Java world, is unique to OSGi environments(semantic versioning, 2010).

3 INTRABUNDLE - AN OSGI BUNDLE INTROSPECTION TOOL

With was clear in previous chapters that with all the presented differences between modular and non modular applications that the first need different approaches

3.1 Introduction

3.2 Design Decisions

To analyze large code bases of OSGi projects which can vary from KLOCs to thousands of KLOCs we needed a lightweight approach with the following functional requirements:

-

The following alternatives were evaluated:

-

3.3 JBoss Forge

3.4 Implementation Overview

3.5 Collecting Bundle Data

3.6 Metrics Calculation

3.7 Intrabundle Quality

In this section we will see how Intrabundle's quality is managed and how some concepts of *section 2.1* were applied to the project.

3.7.1 Internal quality

Intrabundle internal is managed by PMD and JaCoCo. PMD is an static analysis tool and JaCoCo a dynamic analysis one. Both were presented at Chapter two in section *Quality Analysis Tools* with the objective to guarantee non functional requirements.

3.7.1.1 Example

PMD was already illustrated at Chapter 2 as an example of static analysis tool. JaCoCo is used to calculate code coverage to track files and methods that automated tests are covering. Figure 3.1 shows JaCoCo code coverage report for Intrabundle:

Figure 3.1: Intrabundle code coverage

intrabundle

Element	Missed Instructions	Cov.	Missed Branches	Cov.	Missed	Cxty	Missed	Lines	Missed	Methods	Missed	Classes
br.ufrgs.rmpestano.intrabundle.factory		100%		83%	1	6	0	6	0	3	0	1
br.ufrgs.rmpestano.intrabundle.event		100%		n/a	0	3	0	5	0	3	0	2
br.ufrgs.rmpestano.intrabundle.locator		97%		70%	3	11	2	34	0	6	0	2
br.ufrgs.rmpestano.intrabundle.jdt		95%		88%	2	11	1	18	1	7	0	2
br.ufrgs.rmpestano.intrabundle.plugin		89%		80%	27	114	20	251	4	54	0	4
br.ufrgs.rmpestano.intrabundle.facet		89%		73%	15	38	7	40	3	16	0	4
br.ufrgs.rmpestano.intrabundle.model		81%		61%	138	289	101	497	11	89	0	7
br.ufrgs.rmpestano.intrabundle.metric		78%		64%	15	40	21	100	0	13	0	2
br.ufrgs.rmpestano.intrabundle.util		76%		64%	67	140	52	197	4	34	0	7
br.ufrgs.rmpestano.intrabundle.i18n		67%		100%	0	6	3	12	0	5	0	1
Total	1,040 of 6,080	83%	293 of 852	66%	268	658	207	1,160	23	230	0	32

Created with JaCoCo 0.7.1

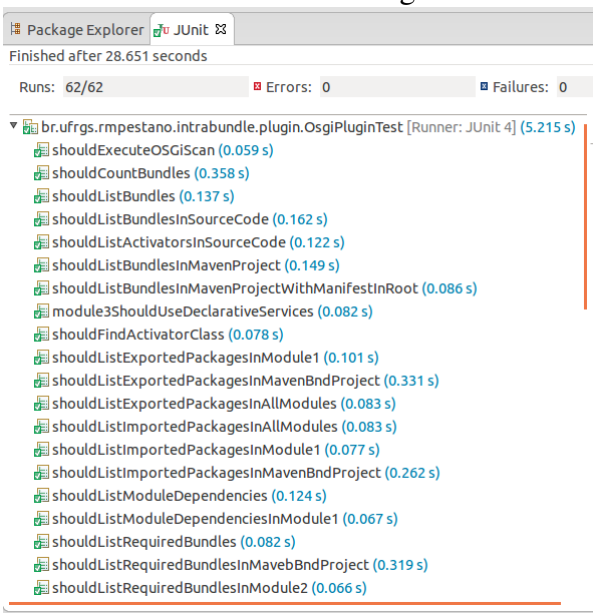
3.7.2 External quality

Intrabunde external quality is assured by automated whitebox tests so we can verify if Intrabundle is working as expected, if it meets its functional requirements.

3.7.2.1 Example

As of November 2014 Intrabundle performs 62 **integration tests** which can be defined as automated tests aimed to detect any inconsistencies between the software units that are integrated together. In this kind of automated tests the system must be running and in case of Intrabundle we also need the Forge runtime up and running during tests and that is done by Arquillian (dan, 2011), an integration test platform. Figure 3.2 shows the result of integration tests execution:

Figure 3.2: Intrabundle external tests



4 BUNDLE INTROSPECTION RESULTS

This chapter will make a deep analysis of results and prove that my contribution is valid(or not)

5 CONCLUSION

REFERENCES

BEOHM, B.; BASILI, V. R. Software Defect Reduction Top 10 List. **Computer**, Los Angeles, v. 34, no. 1, pp 135-137, January 2001.

KHAN, M. E.; KHAN, F. A Comparative Study of White Box, Black Box and Grey Box Testing Techniques. **International Journal of Advanced Computer Science and Applications**, New York, v. 3, no. 6, pp 12-15, June 2012.

KNORR, E. What microservices architecture really means. **InfoWorld**, Available at:<http://www.infoworld.com/article/2682502/application-development/application-development-what-microservices-architecture-really-means.html>. Accessed in: November 2014.

KRILL, P. Project Jigsaw delayed until Java 9. **InfoWorld**, Available at:<http://www.infoworld.com/article/2617584/java/project-jigsaw-delayed-until-java-9.html>. Accessed in: November 2014.

HAMZA, S.; SADOU, S.; FLEURQUIN, R.
Measuring Qualities for OSGi Component-Based Applications. **International Conference on Quality Software**, Najing, pp 25-34, July 2013.

CISQ. Specification for Automated Quality Characteristic Measures. **CISQ quality standard version 2.1**. Available at:<http://it-cisq.org/wp-content/uploads/2012/09/CISQ-Specification-for-Automated-Quality-Characteristic-Measures.pdf>. Accessed in: November 2014.

SQA. Software Quality Metrics. [S.l.:s.n]. Available at:<http://www.sqa.net/softwarequalitymetrics.html>. Accessed in: November 2014

ISO25010:2011 System and software quality models. **Systems and software Quality Requirements and Evaluation (SQuaRE)**. Available at:<http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=35733>. Accessed in: November 2014.

Wichmann, B. A.; Canning, A. A.; Clutterbuck, D. L.; Winsbarrow, L. A.; Ward, N. J.; Marsh, D. W. R. Industrial Perspective on Static Analysis. **Software Engineering Journal**, [S.l], v. 10, pp 69–75, Mar 1995.

Intrabundle PMD ruleset. Available at:<https://github.com/rmpestano/intrabundle/tree/master/src/test/resources/rulesets/pmd.xml>. Accessed in: November 2014.

Dan Allen. Arquillian - A Component Model for Integration Testing. **Jaxenter**, Mar 2011. Available at:<http://jaxenter.com/arquillian-a-component-model-for-integration-testing-103003.html>. Accessed in: November 2014.

IEEE Spectrum. Top 10 Programming Languages. **Spectrum's 2014 Ranking**, Jul 2014. Available at:<http://spectrum.ieee.org/computing/software/top-10-programming-languages>. Accessed in: November 2014.

Arnold K.; Gosling J.; Holmes D. **THE Java™ Programming Language**. 4th Edition. [S.l]:Addison Wesley Professional, 2005

Hall, R. S.; Pauls K.; McCulloch S.; Savage D. **OSGi in Action**:Creating Modular Applications in Java. 1st Edition, Stamford: Manning Publications Co., 2011

Kan S. H. **Metrics and Models in Software Quality Engineering**. 2nd Edition [S.l]: Addison Wesley, 2002. p. 113-114

Semantic Versioning. Available at:<http://www.osgi.org/wiki/uploads/Links/SemanticVersioning.pdf>. Accessed in: November 2014.

OSGi Framework Architecture - Three Conceptual Layers. Available at:<http://www.programcreek.com/2011/07/osgi-framework-architecture-three-conceptual-layers/>. Accessed in: November 2014.

Evans, E.; Fowler, M. **Domain-Driven Design**: Tackling Complexity in the Heart of Software. 1st Edition, [S.l]: Prentice Hall, August 2003