README

Developed by João Campelo (1151386)

This folder includes all artifacts developed for the First Part of the QESOFT Project.

It is structured as follows:

1. Introduction

The first phase of the QESOFT project analyzes the project in an operational environment to determine whether or not the project is reusable.

The main focus is the quality attributes and architectural characteristics that must be considered throughout the study, such as maintenance, performance, safety vulnerabilities, construction compliance, and adequate testing, which are key issues

In order to identify and select the best materials, this research will take an objective approach.

The paper also describes the project's learning environment, including how to choose a Java service-based application with multiple executable REST controllers or DDD sets with multiple endpoints that can allow for the distribution of work among team members in this application. The software should also be SMART compliant and enable complete data generation.

This report will focus only on the **DataProductsController** and its dependencies.

2. Maintainability

Software maintainability refers to the ability of a software system to undergo modifications or updates with ease, accuracy, and minimum risks. It is one of the key attributes of software quality that ensures the longevity and sustainability of a software application [1] [2] [3].

Maintainability is crucial in the software development lifecycle, as software systems inevitably evolve due to changing requirements, new technologies, or the need to fix bugs and issues. Poorly maintained software can quickly become unmanageable and difficult to update, leading to increased costs, longer development cycles, and even business disruptions [4].

The Maintainability Index first appeared in 1992 when it was proposed by Paul Oman and Jack Hagemeister at the International Conference on Software Maintenance to establish automated software development metrics to guide software-related decision-making. The Maintainability Index tries to give a holistic view of the relative maintenance burden for different sections of a project by blending a series of different metrics [5] [6].

Using a more modern adaptation of the original formula proposed in 2011 by Microsoft:

```
Maintainability Index = MAX(0,(171 - 5.2 * ln(Halstead Volume) - 0.23 * (Cyclomatic Complexity) - 16.2 * ln(Lines of Code))*100 / 171)
```

On the formula above, the Maintainability Index formula uses three other metrics values.

- Halstead Volume is a measure of the program's size and is calculated by counting the number of unique operators and operands used in the code.
- Cyclomatic Complexity is a measure of the program's structural complexity and is calculated by counting the number of decision points (e.g., if statements, loops, switches) in the code.
- Lines of Code is the number of lines of code in the software system.

The MI formula is designed to provide a score between 0 and 100, where higher scores indicate better maintainability. A score above 85 is considered to be excellent, while scores below 20 are considered to be very poor. As a general rule of thumb:

Score	Classification
0 - 20	Very Poor
20 - 40	Bellow Average

Score	Classification
40 - 70	Average
70 - 100	Good to Excellent

In this part was used MetricsTree [7] - IntelliJ IDEA Plugin - helps to evaluate the project maintainability index for which class or methods.

The **DataProductsController** class has a Maintainability Index of **45.2676** this is classified as ***Average*** even though the project has a result of **71.0886**.

After analyzing the Maintainability Index of the class, it proceeds to analyze the class methods to understand which methods can be improved:

Method	Maintainability Index	Classification
DataProductsController()	70.2303	**Good to Excellent**
create(ProductPojo)	71.432	**Good to Excellent**
delete(Map<String,String>)	71.3233	**Good to Excellent**
getOrderSpecMap()	82.6511	**Good to Excellent**
readMany(Map<String,String>)	75.7988	**Good to Excellent**
update(ProductPojo, Map<String,String>)	70.9324	**Good to Excellent**
uploadCsv(MultipartFile)	64.338	**Average**

2.1 Propagation Cost

The Propagation Cost (PC) metric is a measure of the cost and effort required to make a change in a single component of a system or to propagate this change through the system. This implies the time and resources required to identify the components that need to be updated, make the necessary changes, and test the system to ensure that the changes did not introduce any new issues.

2.1.1. *DataProductsController* Aggregate

Total Components = 21

Cumulative Component Dependency (CCD)

CCD = Total Dependencies = 64

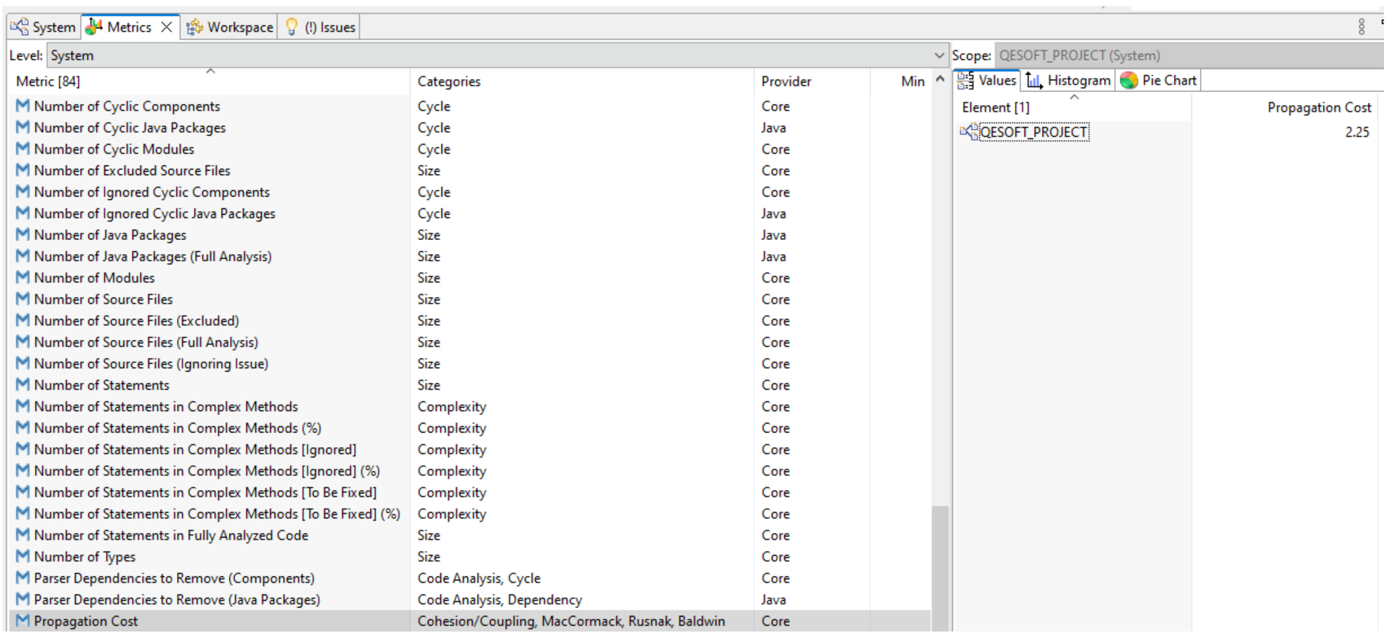
Average Component Dependency (ACD)

ACD = CCD / Total Components = 64 / 21 = 3.048

Propagation Cost (PC)

PC = ACD / Total Components = 3.048 / 21 = 0.1451

2.1.2 Project



Level: System

Scope: QESOFT_PROJECT (System)

Metric [84]	Categories	Provider	Min
Number of Cyclic Components	Cycle	Core	
Number of Cyclic Java Packages	Cycle	Java	
Number of Cyclic Modules	Cycle	Core	
Number of Excluded Source Files	Size	Core	
Number of Ignored Cyclic Components	Cycle	Core	
Number of Ignored Cyclic Java Packages	Cycle	Java	
Number of Java Packages	Size	Java	
Number of Java Packages (Full Analysis)	Size	Java	
Number of Modules	Size	Core	
Number of Source Files	Size	Core	
Number of Source Files (Excluded)	Size	Core	
Number of Source Files (Full Analysis)	Size	Core	
Number of Source Files (Ignoring Issue)	Size	Core	
Number of Statements	Size	Core	
Number of Statements in Complex Methods	Complexity	Core	
Number of Statements in Complex Methods (%)	Complexity	Core	
Number of Statements in Complex Methods [Ignored]	Complexity	Core	
Number of Statements in Complex Methods [Ignored] (%)	Complexity	Core	
Number of Statements in Complex Methods [To Be Fixed]	Complexity	Core	
Number of Statements in Complex Methods [To Be Fixed] (%)	Complexity	Core	
Number of Statements in Fully Analyzed Code	Size	Core	
Number of Types	Size	Core	
Parser Dependencies to Remove (Components)	Code Analysis, Cycle	Core	
Parser Dependencies to Remove (Java Packages)	Code Analysis, Dependency	Java	
Propagation Cost	Cohesion/Coupling, MacCormack, Rusnak, Baldwin	Core	

Element [1]	Propagation Cost
QESOFT_PROJECT	2.25

Conclusion

Considering that the number of components in the system is less than 500, the system is considered a small system. So it can be concluded that obtaining propagation cost values are of no concern given the size of the system. However, we can observe that any change in the DataProductsController will not have a big impact on the system, but any change in the system may have an impact on the DataProductsController.

2.2 Size metric

Lines of Code (LoC) per file counts every line that contains actual code and skips empty lines and comment lines.

Total Lines metric counts every single line, including empty lines and comment lines.

Number of Statements verifies the statements, i.e., s a single complete action performed in the source code, usually terminated by a special character or a newline.

In the class **DataProductsController** it was possible to determine the following values:

Lines of Code: 108 Total Lines: 151 Number of Statements: 6

These values can indicate how much the component is doing and how complex it is. So, we can say that this component is not complex.

2.3 Cyclomatic complexity

In 1976, Thomas J. McCabe presents a metric for measuring the complexity of a software program, which he calls "cyclomatic complexity."[8]. This metric is based on the number of control flow statements in the program, such as loops and conditionals, and provides a quantitative measure of the program's complexity.

For this metric, it was analyzed the metric Average Complexity that is described as the weighted average modified extended cyclomatic complexity for fully analyzing code.

Average Complexity: 1,00

We may conclude that the class **DataProductsController** is simple to comprehend and doesn't pose a significant danger when modified because the value calculated is relatively low.

3. Performance

3.1. Key Performance Indicators (KPIs)

Key Performance Indicators (KPIs) are measurements for assessing how well an organization, business unit, or person is performing in reaching particular goals. KPIs are used to gauge success in achieving objectives and to pinpoint areas that require improvement.

KPIs can assess financial, operational, consumer, employee, or environmental performance and can be quantitative or qualitative. Revenue growth, customer happiness, employee retention rates, and environmental impact measurements are a few examples of KPIs.

KPIs are often selected based on their applicability to the strategic objectives of the firm, and they should be monitored over time to spot patterns and possibilities for development. They can be used to promote continuous development and make sure that resources are being used efficiently. They are a crucial tool for measuring and managing performance [9].

KPI Metrics	Description
CPU utilization	It measures the percentage of CPU usage while the application or system is running.
Concurrency	It measures the ability of the system or application to handle multiple concurrent requests.
Error Rates	It is the percentage of requests resulting in errors compared to the total number of requests.
Memory Usage	It measures the amount of memory used by the system or application during execution.
Peak Response Time	It measures the roundtrip of a request/response cycle but focuses on the longest cycle rather than taking an average.
Requests per Second (RPS)	It is the number of requests an information retrieval system such as a search engine handles in one second.
Thread Counts	It is the number of concurrent requests that the server receives at a particular time.
Throughput	It measures the number of requests an application can handle in a second.

3.2. Tests

We choose JMeter which is a widely used tool for load testing, performance testing, and stress testing web applications. The fact that JMeter is open-source and cost-free to use is one of the reasons you might think about adopting it for your application rather than another one.

JMeter also has the benefit of being platform-independent. It is a Java-based program that can be used with Windows, Linux, macOS, or any other platform that supports Java.

JMeter is quite adaptable, so you can alter it to meet your particular testing needs. To make sure that your tests truly reflect the usage patterns of your application, you can configure several factors including the number of threads, ramp-up time, and loop count.

The extensive list of protocols that JMeter supports also includes HTTP, HTTPS, FTP, JDBC, SOAP, REST, and many others. This implies that regardless of the protocols your application utilizes, you may test its performance and scalability.[10]

NOTE: To present the results, we used an **Aggregated Report**

Based on the results of the performed test, we can draw the following conclusions:

Average Response Time: The average response time is 6 milliseconds, which indicates that the application is responding quickly and efficiently.

Median Response Time: The median response time is 5 milliseconds, which indicates that most of the requests are being processed in a very short time.

90% Line: 90% of the requests were completed in less than 12 milliseconds, which is excellent performance for the application.

Throughput: The throughput of the application is 1823.2 transactions per second, which is a high rate for an application with 200 simulated users.

Errors: There were no errors recorded during the test, which indicates that the application is running stably.

3.2.1. Load Tests

To execute a load test for the application, we simulate 100 users doing GET and Post requests. So we define the following thread properties:

- Number of threads (users): 100
- Ramp-up period (how long it takes to "ramp up" to the full number of threads chosen, in seconds): 0
- Loop Count: 1

3.2.1.1. Get Products Request

# Samples	Average	Median	90% Line	95% Line	99% Line	Min	Max	Error %	Throughput	Received KB/sec	Sent KB/sec
100	119	105	216	256	279	20	286	0.0	240.4/sec	404.94	29.58

3.2.1.2. Create Products Request

# Samples	Average	Median	90% Line	95% Line	99% Line	Min	Max	Error %	Throughput	Received KB/sec	Sent KB/sec
100	100	95	193	201	229	8	241	42.00	278.6/sec	124.03	100.59

3.2.1.3. CSV Upload Request

# Samples	Average	Median	90% Line	95% Line	99% Line	Min	Max	Error %	Throughput	Received KB/sec	Sent KB/sec
100	397	404	450	452	461	299	471	0.0	208.8/sec	94.60	385.18

3.2.2. Stress Tests

For this type of test, we used the bzm - concurrency thread group plugin. To execute a Stress Test for the application, we simulate 10 target concurrencies doing GET and POST requests and this will be held for 30 seconds. So we define the following thread properties:

- Target Concurrency: 10
- Ramp-Up time (seconds): 5
- Ramp-Up Steps Count:
- Hold Target Rate Time (seconds): 30

3.2.2.1. Get Products Request

# Samples	Average	Median	90% Line	95% Line	99% Line	Min	Max	Error %	Throughput	Received KB/sec	Sent KB/sec
25378	11	8	15	22	79	4	104	39.48	719.1/sec	1378.31	53.56

3.2.2.2. Create Products Request

# Samples	Average	Median	90% Line	95% Line	99% Line	Min	Max	Error %	Throughput	Received KB/sec	Sent KB/sec
4001	86	17	39	115	1964	4	7285	75.43	100.2/sec	49.13	36.18

3.2.2.3. CSV Upload Request

# Samples	Average	Median	90% Line	95% Line	99% Line	Min	Max	Error %	Throughput	Received KB/sec	Sent KB/sec
16142	19	6	16	21	183	3	3376	99.89	450.8	199.81	145.48

3.2.3. Soak Tests

For this type of test, we used the jp@gc - ultimate thread group plugin. To execute a Soak Test for the application, we simulate 10 target concurrencies doing GET and POST requests and this will be held for 30 seconds. So we define the following thread properties:

- Start Thread Count: 10
- Initial Delay (seconds): 0
- Startup Time (seconds): 10
- Hold Load For(sec): 20
- Shutdown Time (seconds): 10

3.2.3.1. Get Products Request

# Samples	Average	Median	90% Line	95% Line	99% Line	Min	Max	Error %	Throughput	Received KB/sec	Sent KB/sec
35935	8	5	29	35	41	1	166	57.25	921.4/sec	1393.01	48.47

3.2.3.2. Create Products Request

# Samples	Average	Median	90% Line	95% Line	99% Line	Min	Max	Error %	Throughput	Received KB/sec	Sent KB/sec
4118	83	6	13	19	554	1	14247	76.06	95.4/sec	46.85	34.44

3.2.3.3. CSV Upload Request

# Samples	Average	Median	90% Line	95% Line	99% Line	Min	Max	Error %	Throughput	Received KB/sec	Sent KB/sec

# Samples	Average	Median	90% Line	95% Line	99% Line	Min	Max	Error %	Throughput	Received KB/sec	Sent KB/sec
16978	20	3	9	12	489	1	15555	99.89	389.5/sec	172.66	125.71

3.3. Conclusions

The Load tests for **Get Products** and **CSV Upload** requests finished with 0% error rates, but it can increase the number of users or the number of loops to have a full picture of this controller's performance. In the case of **Create Products** request indicates that the system is not able to handle the load and is not performing as expected under normal or heavy load conditions. Such a high error rate suggests that the system is not stable and may not be able to handle the expected traffic or user load in production.

The Stress Tests error rate is higher than 39%, which indicates that the system is unable to handle the load and is not performing as expected under high-stress conditions. Such a high error rate suggests that the system is not stable and may fail when it is put under significant stress. It is critical to identify and resolve the causes of these errors before releasing the system into production.

The Soak Tests error rate is higher than 57%, it indicates that the project is not performing as expected under this use. This rate suggests that this project is not stable and its performance may degrade significantly over time.

To solve the problems mentioned above, it is essential to analyze the soak test results and determine the root cause of the high error rate. This may require additional testing and debugging to identify specific issues. Once the issues have been identified, they can be addressed through bug fixes, system updates, or other measures.

The CSV Upload Request tests are not accurate because the test is only picking up the first row of the CSV file, this explains the high error rate.

4. Security

4.1. Tool

In this part, we used the FindBugs IntelliJ IDEA plugin which is a powerful tool for improving the quality and reliability of Java code, helping developers catch potential issues early in the development process and reducing the risk of bugs and vulnerabilities in production [11].

DataProductsController: 0 vulnerabilities

PaginationServiceImpl: 1 vulnerability

Class	Method	Type	Problem	Field	Priority	Description
PaginationServiceImpl	PaginationServiceImpl()	May expose internal representation by incorporating reference to mutable object	Malicious code vulnerability	apiProperties	Medium Confidence Malicious code vulnerability	This code stores a reference to an externally mutable object into the internal representation of the object. If instances are accessed by untrusted code, and unchecked changes to the mutable object would compromise security or other important properties, you will need to do something different. Storing a copy of the object is a better approach in many situations.

ProductsCrudServiceImpl: 1 vulnerability

Class	Method	Type	Problem	Field	Priority	Description

Class	Method	Type	Problem	Field	Priority	Description
ProductsCrudServiceImpl	ProductsCrudServiceImpl()	May expose internal representation by incorporating reference to mutable object	Malicious code vulnerability	productImagesRepository	Medium Confidence Malicious code vulnerability	This code stores a reference to an externally mutable object into the internal representation of the object. If instances are accessed by untrusted code, and unchecked changes to the mutable object would compromise security or other important properties, you will need to do something different. Storing a copy of the object is a better approach in many situations.

Class	Method	Type	Problem	Field	Priority	Description
ProductsCrudServiceImpl	ProductsCrudServiceImpl()	May expose internal representation by incorporating reference to mutable object	Malicious code vulnerability	productsRepository	Medium Confidence Malicious code vulnerability	This code stores a reference to an externally mutable object into the internal representation of the object. If instances are accessed by untrusted code, and unchecked changes to the mutable object would compromise security or other important properties, you will need to do something different. Storing a copy of the object is a better approach in many situations.

ProductPojo: 8 vulnerability

Class	Method	Type	Problem	Field	Priority	Description
ProductPojo	ProductPojo()	May expose internal representation by incorporating reference to mutable object	Malicious code vulnerability	category	Medium Confidence Malicious code vulnerability	This code stores a reference to an externally mutable object into the internal representation of the object. If instances are accessed by untrusted code, and unchecked changes to the mutable object would compromise security or other important properties, you will need to do something different. Storing a copy of the object is a better approach in many situations.

Class	Method	Type	Problem	Field	Priority	Description
ProductPojo	ProductPojo()	May expose internal representation by incorporating reference to mutable object	Malicious code vulnerability	images	Medium Confidence Malicious code vulnerability	This code stores a reference to an externally mutable object into the internal representation of the object. If instances are accessed by untrusted code, and unchecked changes to the mutable object would compromise security or other important properties, you will need to do something different. Storing a copy of the object is a better approach in many situations.
ProductPojo	getCategory()	May expose internal representation by incorporating reference to mutable object	Malicious code vulnerability	category	Medium Confidence Malicious code vulnerability	Returning a reference to a mutable object value stored in one of the object's fields exposes the internal representation of the object. If instances are accessed by untrusted code, and unchecked changes to the mutable object would compromise security or other important properties, you will need to do something different. Returning a new copy of the object is a better approach in many situations.
ProductPojo	getImages()	May expose internal representation by incorporating reference to mutable object	Malicious code vulnerability	images	Medium Confidence Malicious code vulnerability	Returning a reference to a mutable object value stored in one of the object's fields exposes the internal representation of the object. If instances are accessed by untrusted code, and unchecked changes to the mutable object would compromise security or other important properties, you will need to do something different. Returning a new copy of the object is a better approach in many situations.
ProductPojo	setCategory()	May expose internal representation by incorporating reference to mutable object	Malicious code vulnerability	category	Medium Confidence Malicious code vulnerability	This code stores a reference to an externally mutable object into the internal representation of the object. If instances are accessed by untrusted code, and unchecked changes to the mutable object would compromise security or other important properties, you will need to do something different. Storing a copy of the object is a better approach in many situations.

Class	Method	Type	Problem	Field	Priority	Description
ProductPojo	setImages()	May expose internal representation by incorporating reference to mutable object	Malicious code vulnerability	images	Medium Confidence Malicious code vulnerability	This code stores a reference to an externally mutable object into the internal representation of the object. If instances are accessed by untrusted code, and unchecked changes to the mutable object would compromise security or other important properties, you will need to do something different. Storing a copy of the object is a better approach in many situations.
ProductPojo$ProductPojoBuilder	category()	May expose internal representation by incorporating reference to mutable object	Malicious code vulnerability	category	Medium Confidence Malicious code vulnerability	This code stores a reference to an externally mutable object into the internal representation of the object. If instances are accessed by untrusted code, and unchecked changes to the mutable object would compromise security or other important properties, you will need to do something different. Storing a copy of the object is a better approach in many situations.
ProductPojo$ProductPojoBuilder	images()	May expose internal representation by incorporating reference to mutable object	Malicious code vulnerability	images	Medium Confidence Malicious code vulnerability	This code stores a reference to an externally mutable object into the internal representation of the object. If instances are accessed by untrusted code, and unchecked changes to the mutable object would compromise security or other important properties, you will need to do something different. Storing a copy of the object is a better approach in many situations.

Tests:

- BackendAppTest: 0 vulnerabilities
- DataProductsControllerTest: 2 vulnerabilities

Class	Method	Type	Problem	Field	Priority	Description
DataProductsControllerTest	N/A	Class defines a field that masks a superclass field	Correctness	paginationServiceMock	Medium Confidence Correctness	This class defines a field with the same name as a visible instance field in a superclass. This is confusing and may indicate an error if methods update or access one of the fields when they wanted the other.

Class	Method	Type	Problem	Field	Priority	Description
DataProductsControllerTest	N/A	Class defines a field that masks a superclass field	Correctness	sortServiceMock	Medium Confidence Correctness	This class defines a field with the same name as a visible instance field in a superclass. This is confusing and may indicate an error if methods update or access one of the fields when they wanted the other.

5. Architecture Compliance

Software architectural compliance refers to the degree to which software components and their interactions conform to an established software architecture. It involves verifying that the implemented design and code conform to the intended architecture and that the system functions properly within the constraints set by the architecture.

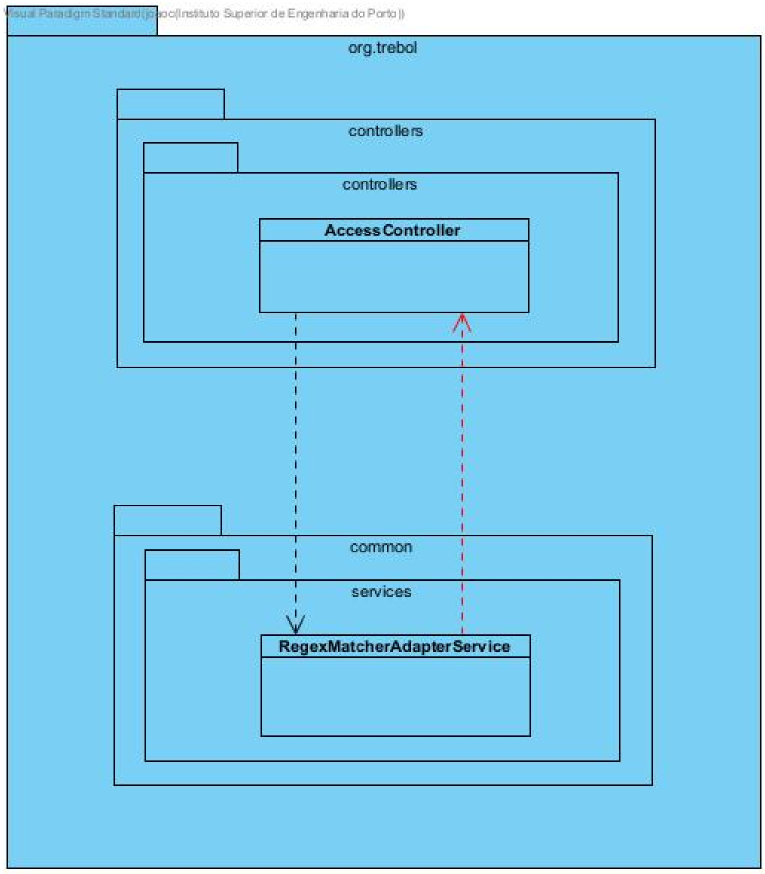
The process of ensuring software architectural consistency typically involves a combination of reviews, inspections, and testing. This can be achieved through manual code reviews, automated testing tools, and analyzing system metrics to identify deviations from the intended architecture.

Adherence to software architecture is critical to the success of software projects. It allows developers to create scalable, maintainable, and extensible systems. It also ensures that the software is reliable, secure and works optimally under various operating conditions.

5.1. Architecture

Classes free from Cycles

```
  @ArchTest
  public static final ArchRule classesShouldBeFreeOfCycles = slices().matching("org.trebol.
(*)..").should().beFreeOfCycles();
```

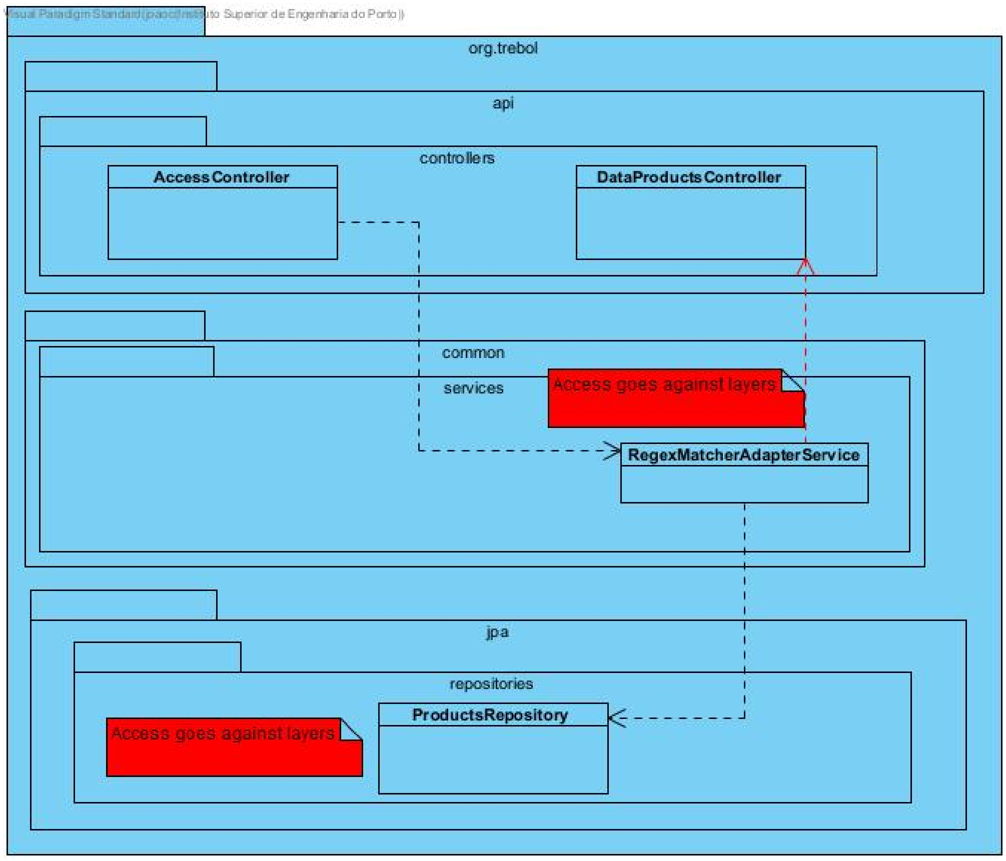

Visual Paradigm Standard(jsoc(Instituto Superior de Engenharia do Porto))
org.trebol
controllers
controllers
AccessController
common
services
RegexMatcherAdapterService

This fitness function checks that there are no cycles in the dependencies inside the package org.trebol. This checks that there are no circular dependencies between different classes.

The project failed this test because there are 92 violations of this test. It seems that it has dependencies between the slices org.trebol.api and org.trebol.common.

Layered Architecture

```
@ArchTest
public static final ArchRule layeredArchitecture = layeredArchitecture().consideringOnlyDependenciesInLayers()
  .layer("Controller").definedBy("org.trebol.api.controllers..")
  .layer("Service").definedBy("org.trebol.api.services.impl..")
  .layer("Repository").definedBy("org.trebol.jpa.repositories..")
  .whereLayer("Controller").mayNotBeAccessedByAnyLayer()
  .whereLayer("Service").mayOnlyBeAccessedByLayers("Controller")
  .whereLayer("Repository").mayOnlyBeAccessedByLayers("Service");
```


Visual Paradigm Standard(paoc(Instituto Superior de Engenharia do Porto))
org.trebol
api
controllers
AccessController
DataProductsController
common
services
Access goes against layers
RegexMatcherAdapterService
jpa
repositories
ProductsRepository
Access goes against layers

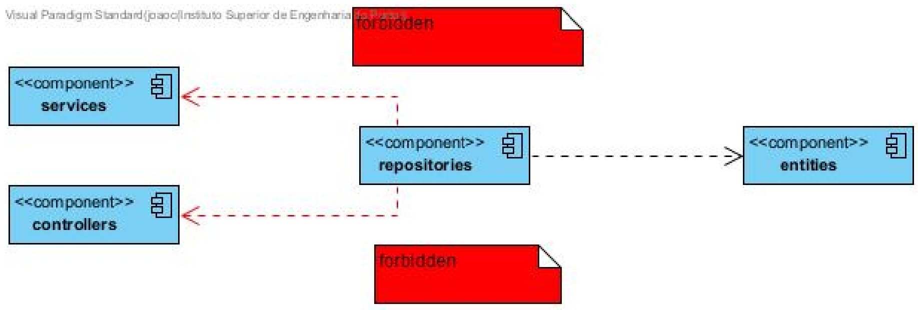
The purpose of this test is to verify the layered architecture pattern. The controllers' layer cannot be accessed by any layer, the service layer can only be accessed by the controllers' layer, and the repository layer can only be accessed by the service layer.

This violation occurred 32 times in the system, part of this violation happens because this type of test can not distinguish the test classes from the others.

Layers Dependencies

Repositories do not depend on Services and Controllers

```
@ArchTest
public static final ArchRule repositoriesShouldNotDependOnEachOther =
  noClasses().that()
    .resideInAnyPackage("org.trebol.jpa.repositories..")
    .and()
    .haveSimpleNameNotContaining("Test")
    .and()
    .areNotInterfaces()
    .should().dependOnClassesThat().resideInAnyPackage("org.trebol.api.services.impl..",
"org.trebol.api.controllers..")
    .allowEmptyShould(true);
```


Visual Paradigm Standard(joaoc(Instituto Superior de Engenharia do Porto))
forbidden
<<component>> services
<<component>> repositories
<<component>> entities
<<component>> controllers
forbidden

The purpose of this test is to verify if repositories do not have dependencies on services and controllers. This test passed successfully.

Controllers depend on Services and Repositories

```
    @ArchTest
    public static final ArchRule controllersShouldDependsOnServicesAndRepositories =
      classes().that()
        .resideInAnyPackage("org.trebol.api.controllers..")
        .and()
        .haveSimpleNameNotContaining("Test")
        .and()
        .areNotInterfaces()
        .should().dependOnClassesThat().resideInAnyPackage("org.trebol.api.services.impl..",
  "org.trebol.jpa.repositories..");
```

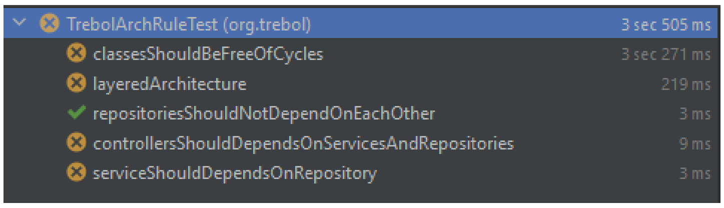
The purpose of this test is to verify if controllers do have dependencies to services or repositories. This violation occurred 21 times.

Service depends on Repository

```
    @ArchTest
    public static final ArchRule serviceShouldDependsOnRepository =
      classes().that()
        .resideInAPackage("org.trebol.api.services.impl..")
        .and()
        .areNotInterfaces()
        .and()
        .haveSimpleNameEndingWith("ServiceImpl")
        .and()
        .haveSimpleNameNotContaining("Test")
        .should().dependOnClassesThat().resideInAnyPackage("org.trebol.jpa.repositories..");
```

The purpose of this test is to verify if services do have dependencies repositories. This violation occurred 2 times.

Results



```
TrebolArchRuleTest (org.trebol)                       3 sec 505 ms
  classesShouldBeFreeOfCycles                         3 sec 271 ms
  layeredArchitecture                                 219 ms
  repositoriesShouldNotDependOnEachOther              3 ms
  controllersShouldDependsOnServicesAndRepositories   9 ms
  serviceShouldDependsOnRepository                    3 ms
```

5.2. Controller

Inheritance

```
    @ArchTest
    public static final ArchRule controllersShouldBeController =
      classes().that()
        .areAnnotatedWith(RestController.class)
        .and()
        .haveSimpleNameNotContaining("Test")
        .should().haveSimpleNameEndingWith("Controller");
```

This fitness function checks that all classes, that have RestController annotation and does not have a name containing "Test", have names that end with "Controller". This test passed successfully.

Annotation

```
@ArchTest
public static final ArchRule classesShouldBeRequestMapping =
  classes().that()
    .areAnnotatedWith(RestController.class)
    .and()
    .haveSimpleNameNotContaining("Test")
    .should().beAnnotatedWith(RequestMapping.class);
```

This fitness function checks that all classes, that have RestController annotation and does not have a name containing "Test", have RequestMapping annotation. This violation occurred 1 time.

Class and package containment

```
@ArchTest
public static final ArchRule controllerClassesShouldResideInControllerPackage =
  classes().that()
    .areAnnotatedWith(RestController.class)
    .and()
    .haveSimpleNameNotContaining("Test")
    .should().resideInAPackage("..controllers..");
```

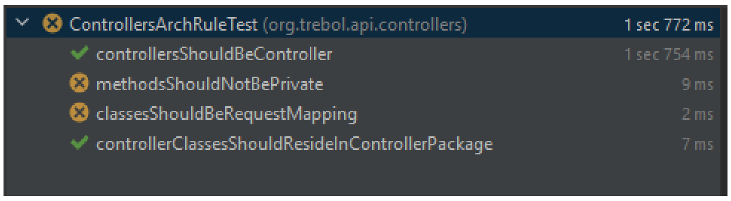
This fitness function checks that all classes, that have RestController annotation and does not have a name containing "Test", reside inside of package "controllers". This test passed successfully.

Non-Private Methods

```
@ArchTest
public static final ArchRule methodsShouldNotBePrivate =
  methods().that()
    .areDeclaredInClassesThat().areAnnotatedWith(RestController.class)
    .and()
    .areNotAnnotatedWith(ExtendWith.class)
    .should().notBePrivate();
```

This fitness function checks that all methods, that its class has RestController annotation and does not have ExtendWith annotation, do not have private methods. This violation occurred 2 times.

Results



```
ControllersArchRuleTest (org.trebol.api.controllers)    1 sec 772 ms
  ✓ controllersShouldBeController                      1 sec 754 ms
  ✗ methodsShouldNotBePrivate                           9 ms
  ✗ classesShouldBeRequestMapping                       2 ms
  ✓ controllerClassesShouldResideInControllerPackage    7 ms
```

5.3. Service

Inheritance

```
@ArchTest
public static final ArchRule servicesShouldBeServiceImpl =
  classes().that()
    .areAnnotatedWith(Service.class)
    .and()
```

```
        .haveSimpleNameNotContaining("Test")
        .should().haveSimpleNameEndingWith("ServiceImpl");
```

This fitness function checks that all classes that have Service annotation, should have names that end with "ServiceImpl". This test passed successfully.

Class and package containment

```
    @ArchTest
    public static final ArchRule serviceClassesShouldResideInServicePackage =
      classes().that().
        areAnnotatedWith(Service.class)
        .and()
        .areNotInterfaces()
        .should().resideInAPackage("..services..");
```

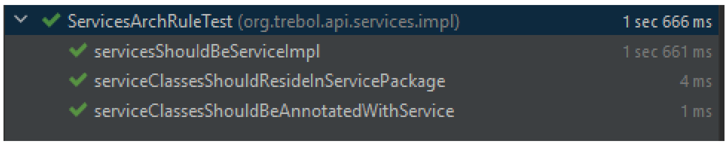
This fitness function checks that all classes, that have Service annotation and are not an Interface, reside inside of package "services". This test passed successfully.

Annotation

```
    @ArchTest
    public final ArchRule serviceClassesShouldBeAnnotatedWithService =
      classes().that()
        .resideInAPackage("..services..")
        .and()
        .areNotInterfaces()
        .and()
        .haveSimpleNameNotContaining("Test")
        .and()
        .haveSimpleNameEndingWith("ServiceImpl")
        .should().beAnnotatedWith(Service.class);
```

This fitness function checks that all classes, that reside inside a package "services", are not an Interface, do not have a name containing "Test" and its name ends with "ServiceImpl", and have Service annotation. This test passed successfully.

Results

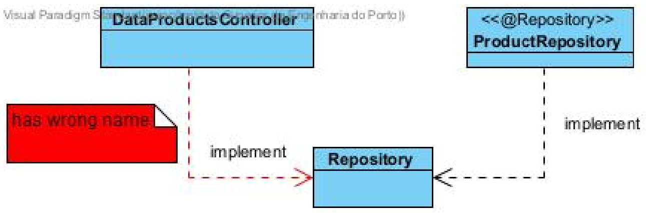


```
✓ ServicesArchRuleTest (org.trebol.api.services.impl)    1 sec 666 ms
  ✓ servicesShouldBeServiceImpl                          1 sec 661 ms
  ✓ serviceClassesShouldResideInServicePackage                   4 ms
  ✓ serviceClassesShouldBeAnnotatedWithService                   1 ms
```

5.4. Repository

Inheritance

```
  @ArchTest
    public static final ArchRule servicesShouldBeServiceImpl =
      classes().that()
        .areAnnotatedWith(Repository.class)
        .should().haveSimpleNameEndingWith("Repository");
```



This fitness function checks that all classes that have Repository annotation, should have names that end with "Repository". This test passed successfully.

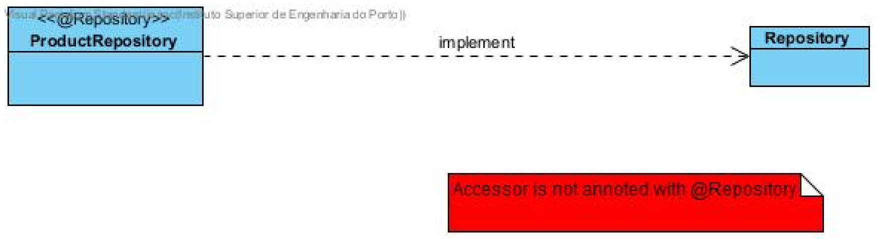
Class and package containment

```
@ArchTest
public static final ArchRule repositoryClassesShouldResideInRepositoryPackage =
  classes().that()
    .areAnnotatedWith(org.springframework.stereotype.Repository.class)
    .should().resideInAPackage("..repositories..");
```

This fitness function checks that all classes, that have Repository annotation, reside inside of package "repositories". This test passed successfully.

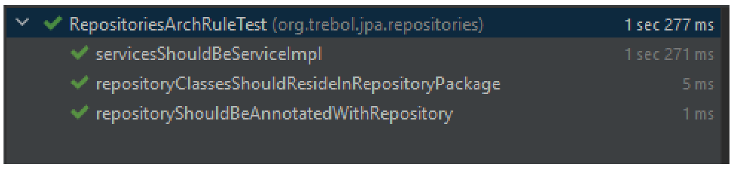
Annotation

```
@ArchTest
public static final ArchRule repositoryShouldBeAnnotatedWithRepository =
  classes().that()
    .resideInAPackage("..repositories..")
    .and()
    .haveSimpleNameNotContaining("Test")
    .should().beAnnotatedWith(Repository.class);
```



This fitness function checks that all classes, that reside inside a package "repositories" and does not have a name containing "Test", have Repository annotation. This test passed successfully.

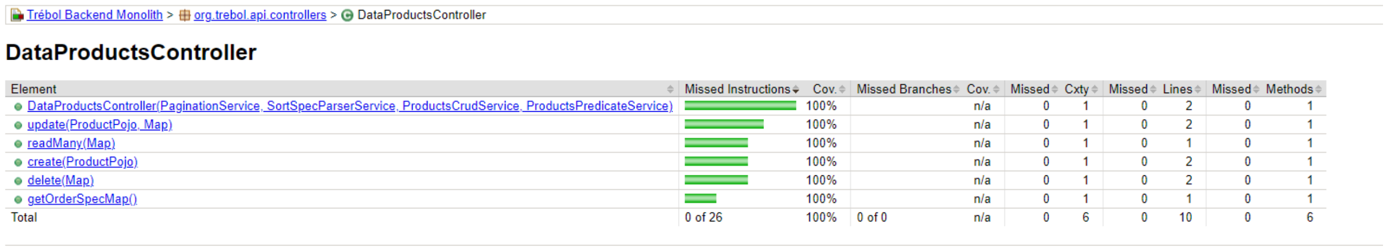
Results



```
✓ RepositoriesArchRuleTest (org.trebol.jpa.repositories)      1 sec 277 ms
    ✓ servicesShouldBeServiceImpl                              1 sec 271 ms
    ✓ repositoryClassesShouldResideInRepositoryPackage                5 ms
    ✓ repositoryShouldBeAnnotatedWithRepository                       1 ms
```

6. Test Examination

6.1 Test Coverage



Trébol Backend Monolith > org.trebol.api.controllers > DataProductsController

DataProductsController

Element	Missed Instructions	Cov.	Missed Branches	Cov.	Missed	Cxty	Missed	Lines	Missed	Methods
DataProductsController(PaginationService, SortSpecParserService, ProductsCrudService, ProductsPredicateService)	🟩	100%		n/a	0	1	0	2	0	1
update(ProductPojo, Map)	🟩	100%		n/a	0	1	0	2	0	1
readMany(Map)	🟩	100%		n/a	0	1	0	1	0	1
create(ProductPojo)	🟩	100%		n/a	0	1	0	2	0	1
delete(Map)	🟩	100%		n/a	0	1	0	2	0	1
getOrderSpecMap()	🟩	100%		n/a	0	1	0	1	0	1
Total	0 of 26	100%	0 of 0	n/a	0	6	0	10	0	6

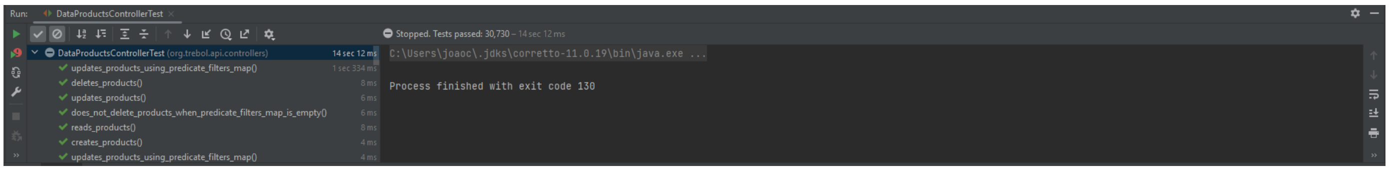
The report provides information about the number of instructions, branches, lines, complexity, and methods that were covered by your test cases. Analyzing the information in the report we can conclude that:

The **"DataSalesController"** element was completely covered by the tests, as the coverage for missed statements and missed branches was 100% and there are no missed lines or methods.

The methods **"update(ProductPojo, Map)"**, **readMany(Map)**, **"create(ProductPojo)"**, **"delete(Map)"** and **"getOrderSpecMap()"** were completely covered by the tests, as the coverage for missed statements and missed branches was 100% and there are no missed lines or methods.

This report can help identify the areas of the codebase that require more testing and improve your test coverage.

6.2 Test Coverage



Run: DataProductsController Test

```
Stopped. Tests passed: 30,730 – 14 sec 12 ms

DataProductsControllerTest (org.trebol.api.controllers)                 14 sec 12 ms
    updates_products_using_predicate_filters_map()                      1 sec 334 ms
    deletes_products()                                                  8 ms
    updates_products()                                                  6 ms
    does_not_delete_products_when_predicate_filters_map_is_empty()      6 ms
    reads_products()                                                    8 ms
    creates_products()                                                  4 ms
    updates_products_using_predicate_filters_map()                      4 ms
```

```
C:\Users\joaoc\.jdks\corretto-11.0.19\bin\java.exe ...

Process finished with exit code 130
```

6.3 Project Test

This project has only 4 types of tests:

- Unit tests: These are tests that verify the behavior of individual components or functions in isolation. They help to catch bugs early in the development cycle and ensure that each component behaves as expected.
- Integration tests: These tests verify that the different components of the application work correctly together. They help to ensure that the application behaves correctly as a whole and that there are no issues with the interactions between different components.
- End-to-end tests: These tests verify the behavior of the application as a whole, including the interactions between the front end and backend. They help to ensure that the application meets the requirements and behaves correctly in real-world scenarios.
- Performance tests: These tests verify the performance of the application under various load conditions. They help to identify potential bottlenecks or performance issues and ensure that the application can handle the expected workload.

6.4 Test Suggestion

This project could implement:

- Mutation Tests: These are tests that involve creating artificial defects or mutations in the code to see if the existing tests can detect them;
- Functional Tests: These are tests that check that an application behaves as expected from a user's perspective;
- Regression Tests: These are tests that check that changes to an application do not cause unexpected issues or break existing functionality;
- Security Tests: These are tests that check that an application is secure and protected from common vulnerabilities;

7. Conclusions

Based on the previous analysis it is possible to conclude that the application can not be reused as a basis for a new project.

However, although the project has good maintainability and test examination, some security vulnerabilities must be carefully validated. In the case of performance, it needs more improvements and analysis.

After analyzing the maintainability, performance, and security, some tests were added to verify the architecture compliance of our application, it was concluded that this was not consistent because, because in the designed tests they are not following the specification there are still functionalities that are not.

The change needed to make this architecture compliant or conformant is simple and consists of moving a file to the most appropriate package for this purpose.

However, in the near future a good practice would be to add these tests in advance of the development adopting strategy like TDD so that it is easier to "guide" developers to adopt the right patterns.

Regarding the unit tests previously defined, we conclude that they are reliable and are covering the full part of the code, with a code coverage of 100%.

8. References

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