Apache Commons-email

Luigi Allocca
l.allocca8@studenti.unisa.it

Rocco Iuliano
r.iuliano13@studenti.unisa.it

Simone Della Porta
s.dellaporta6@studenti.unisa.it

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1 INTRODUCTION

The aim of this project is to analyze and improve an existing project by the Apache foundation. We will improve the availability (i), reliability (ii), safety (iii), security (iv) and resilience (v) of the project in order to improve its dependability. To reach these aspects, we will improve the coverage of the test cases and creating new ones, fix the bugs and reduce security hotspot issues which refer to a specific area or component of a software system that has a higher risk of security vulnerabilities or breaches. These issues are often identified through a security analysis or review, and they can pose a significant threat to the overall security of the system. By removing these security hotspots, the overall security of the project will be improved, reducing the risk of security breaches and protecting sensitive user data. This can lead to increased trust from users and stakeholders, and can help to ensure that the project is compliant with relevant security regulations and standards. Overall the general goals are:

- Fix as many project bugs as possible, prioritizing the crucial bugs;
- Improve the coverage of project testing by developing new test cases and improving the existing ones;
- Minimize the number of code smells;
- Reduce security hotspot issues;
- Verify the project performance;
- Improve the energy consumption;
- Veirfy the tes quality;
- Identify and correct security issues.

2 PROJECT PRE REQUIREMENTS

To improve the dependability of the software with the tools introduced in the course, we choose a project with the following characteristics:

- Git Actions to check code quality, coverage, Java CI and security.
- The project should use Maven to manage the project build, so it should have the pom.xml file.

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3 CONTEXT OF THE PROJECT

Apache Commons-Email is an open source project and it is released in 01/08/2017 and it is available on GitHub to the following link: https://github.com/apache/commons-email. It aims to provide a API for sending email. Apache Commons-Email is built on top of the Java Mail API, which it aims to simplify. This project is composed by twentyfour contributors and has got 78 fork, 5 branches and 1132 commits of which the last commit was made in 18/03/2023 (id commit: *f41dd76*). Moreover, Apache Commons-Email has got three type of actions:

(1) **CodeQL** that allows us to verify the quality of the project;
(2) **Coverage** that allows us to verify the per cent of coverage of project test cases;
(3) **Java CI** that allows us to apply all the test cases to each commit that we make, so we are sure that the changes that we applied to the software doesn't introduce a bug.

Apache Commons-Email has got a user guide and a JavaDoc API documentation that are available at the following link:

- User guide: https://commons.apache.org/proper/commons-email/userguide.html
- JavaDoc: https://commons.apache.org/proper/commons-email/javadocs/api-release/index.html

Some popular Java-based applications that use Apache Commons Email are Apache Jenkins, Apache OFBiz, and Apache Syncope. Additionally, many Java-based web applications and enterprise systems use Apache Commons Email to handle email sending functionality. To apply the changes to the project, we must observe the following rules of Apache commons-email:

(1) No tabs, instead use spaces for indentation.
(2) Respect the code style.
(3) Create minimal diffs - disable on save actions like reformat source code or organize imports. If you feel the source code should be reformatted create a separate PR for this change.
(4) Provide JUnit tests for your changes and make sure your changes don't break any existing tests by running mvn.

4 PRELIMINAR ANALISYS

After selecting the project Commons-email, we have created a fork of the repository and built the project in order to run all test cases which result passed successfully. Then we performed a test push to verify the project actions and check the results.

5 METHODOLOGICAL STEPS CONDUCTED TO ADDRESS THE GOALS

Then we have conducted a preliminar analysis of the project by using *SonarCloud* and *Codecov*. The obtained results are shown in Figure 1 and Figure 2.

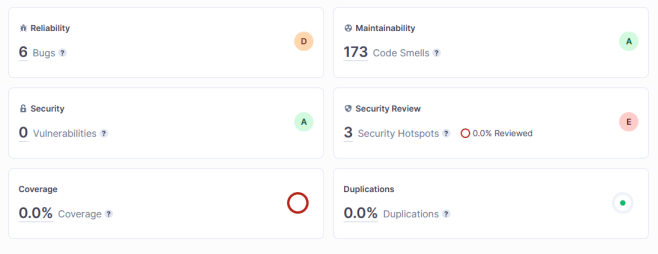


Figure 1: SonarCloud analysis

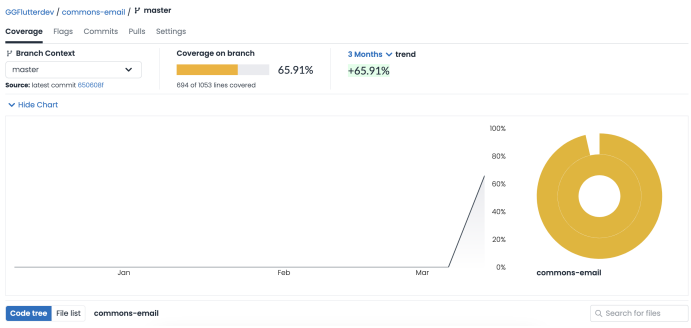


Figure 2: Codecov analysis

The analysis results are:

- The coverage is 65,91%;
- Six bugs which are shown in Table 1;
- Three security hotspots which are shown in Table 2;
- One hundred and seventy-three code smells which are shown in Table 3.

Table 1: Bugs report

Kind of problem	Number	Severity	Topic
Bug	2	Major	Synchronization
Bug	2	Major	NullPointerException
Bug	2	Major	bad formatted try/ catch

Table 2: Security hotspots report

Kind of problem	Number	Severity	Topic
Security hotspot	2	-	DoS attack
Security hotspot	1	-	Weak cryptography

Table 3: Code smells report

Kind of problem	Number	Severity	Topic
Code Smell	11	Bloker	Adding at least one assertion in test cases
Code Smell	3	Critical	Try-catch implementation
Code Smell	5	Critical	Cognitive Complexity allowed
Code Smell	7	Critical	Duplicate literals
Code Smell	7	Major	Commented out code
Code Smell	42	Major	Assert Equals and Assert Not Equals
Code Smell	4	Major	Expressions that are always evaluated to `true`
Code Smell	4	Major	Lambda exceptions
Code Smell	7	Major	Use of a generic exception instead of create and use a dedicated exception
Code Smell	3	Major	Testing
Code Smell	3	Major	Swap arguments
Code Smell	2	Major	Visibility of one constructor
Code Smell	2	Major	Try-catch implementation
Code Smell	1	Major	Number of assertions in a method
Code Smell	1	Major	Nested block of code
Code Smell	1	Major	Usage of a method instead of the usage of another method
Code Smell	1	Major	Usage of the utility of System class instead of the introdiction of a logger
Code Smell	14	Minor	Deprecated code
Code Smell	2	Minor	Chatset name argument
Code Smell	2	Minor	Hard-coded path-delimiter
Code Smell	2	Minor	Try-catch implementation
Code Smell	1	Minor	Return statement
Code Smell	48	Info	Deprecated code

Then for having a continuous analysis of the project we decided to integrate these tools in our project in order to analyze the code after every push or pull request.

5.1 Microservices and Docker

A **microservices architecture** improves the dependability of our project by providing greater fault tollerance, scalability, flexibility

and error isolation in favor of availability. To achieve this, we used **Docker** which lets us to create, deploy, and run applications using containers.

Therefore, we developed this Dockerfile:

```
#We specified the maven version and jdk version that we
     want in our image
FROM maven:3.8.4-openjdk-17-slim AS build

#We created a directory
WORKDIR /app

#We copied the project in the image
COPY src ./src

#We copied the pom file in the image
COPY pom.xml ./

#We copied the conf directory in the image
COPY conf ./conf

#We copied the web application directory in the image
COPY serving-web-content ./serving-web-content

RUN export _JAVA_OPTIONS="-Djavax.net.debug=all"

#Run the commons-email pom
RUN mvn clean package

#Run the web application pom
RUN mvn clean install -f ./serving-web-content/pom.xml

WORKDIR /app/serving-web-content

#We expose the port on which our web application will
     run
EXPOSE 8080

#We run the web application
CMD ["mvn", "spring-boot:run"]
```

In order to share between the members of our team the image of the project we have used **Docker Hub** which is a web-based service that allows us to store, manage, and share docker images. Then we integrated Docker with **CI/CD**, through GitHub actions. Indeed, when we make a commit and the project builds successfully, the Docker image will be updated on Docker Hub. Therefore, all the member of group have a working and updated Docker image of the project with the command docker pull *docker pull –platform linux/x86_64 ggflutter/commons-email* on linux x86_64 or *docker pull ggflutter/commons-email* on other platforms.

5.1.1 *Spring Boot web application.*

We developed a Spring Boot web application for using the services of the Apache commons-email. For developing the web application, we used this link to self-generating it; and we selected these parameters: *"Maven", "Java", "3.1.0", "jar", "jdk-17", "spring-boot-starter-thymeleaf", "spring-boot-starter-web", "spring-boot-devtools"*

Pit Test Coverage Report

Package Summary

org.apache.commons.mail

Number of Classes	Line Coverage		Mutation Coverage	
10	78%	648/832	67%	283/423

Breakdown by Class

Name	Line Coverage		Mutation Coverage	
ByteArrayDataSource.java	0%	0/51	0%	0/26
DefaultAuthenticator.java	100%	4/4	100%	1/1
Email.java	83%	282/339	58%	116/199
EmailAttachment.java	100%	20/20	100%	5/5
EmailException.java	30%	6/20	0%	0/4
EmailUtils.java	86%	59/69	84%	38/45
HtmlEmail.java	82%	128/157	87%	61/70
ImageHtmlEmail.java	93%	37/40	100%	11/11
MultiPartEmail.java	84%	107/127	83%	49/59
SimpleEmail.java	100%	5/5	67%	2/3

Report generated by PIT 1.5.2

Figure 3: Pitest report

and "spring-boot-starter-test". Therefore, we obtained an off-the-shelf web application. For using the functionalities of Apache commons-email in the web application, we used the SimpleEmail class and the send method in EmailController class. After this, we developed the HTML page that contains a form where the user can insert the recipient address for sending mail. Moreover, we copied the web application in the dockerfile to include it in the Docker image. Then, we executed the web application in the Docker container with the last command of the dockerfile. For accessing the web application, we mapped the 8080 port of the Docker container to the 8080 port of our pc.

5.2 Test quality

For evaluating the test quality of commons-email, we used "Pitest". Pitest is a mutation testing tool that can be used to test the effectiveness of a suite of unit tests in detecting faults in code. It works by making small changes to the code and running the unit tests to verify if any of the changes cause the tests to fail. This tool helps us to identify gaps in unit test coverage, by highlighting areas of the code that are not being tested effectively. This can help to improve the overall quality of the codebase by identifying potential issues early in the development process. We used the default mutation criteria for creating mutants (these criteria are available at this link: https://pitest.org/quickstart/mutators/). We chose the Pitest version based on the JUnit, Jupiter and Java versions that our project use. The versions of these tools are:

- The JUnit version is 4.131.2;
- The Jupiter version is 5.9.1;
- The Java version is 11.0.12

For this reason, we used the Pitest version 1.5.2. The results that we obtained after we executed Pitest are shown in Figure 3.

5.3 Energy consumption analysis

Energy consumption analysis is an important activity to ensure the energy efficiency of the application and improve performance. In addition, energy consumption analysis can help ensure that the application is sustainable and has a reduced environmental impact. Also, users complain about the power consumption of their apps and power consumption affects user ratings on app stores.

5.3.1 ***Our analysis with ecoCode.***
Performing an energy consumption analysis of a Java application can help identify the parts of the code that consume the most energy. These parts of the code can then be optimized to reduce the overall consumption of the application. We performed our Analysis using SonarQube, and in particular, the plugin **ecoCode**. EcoCode is a collective project aiming to reduce the environmental footprint of software at the code level. The goal of the project is to provide a list of static code analyzers to highlight code structures that may have a negative ecological impact. The analysis gave us these results:

Table 4: Code smells founded by ecoCode

Topic	Number	Severity
Avoid using global variable	89	Minor
Unused variable	6	Minor
Use switch instead multiple if	70	Minor
Try-with-resources	3	Minor
Avoid the use of Foreach with Arrays	4	Minor
Use ++i instead of i++	6	Minor
Initialize StringBuilder or StringBuffer size	3	Minor
Do not concatenate String in loop (with +)	1	Minor
Do not call a function in for declaration	1	Minor
Return the expression instead of assign it to a local variable	1	Minor

Based on these results, we found a lot of false positives:

- All the elements of the "*Use switch instead multiple if*" class are false positives because the clauses of the if in series regarding different variables or the check is not the equal operator;
- The "*Unused variable*" class elements are false positives because regarding the caught of the exceptions that are necessary for the correct execution;
- The "*Avoid using global variable*" class elements are false positives because the tool suggested not to use the global variable for saving CPU cycles but we should use a local variable that is a copy of the global variable. In our project, these smells regarding the class attributes and if we remove them, it would make a complex refactoring, therefore we do not fix them;
- One smell of the "*Try-with-resources*" class is a false positive because we can not put a class attribute in try-with-resources.

The remaining smells have been fixed based on the tool suggestions. For example, we solved the *Avoid the use of Foreach with Arrays* class casting the simple array in a List for saving CPU cycles calculations and RAM consumption.

5.4 Benchmark testing

Benchmark testing helps measure and compare the performance of the application under different conditions. Furthermore, benchmark testing can help ensure that the application meets performance requirements and can handle expected levels of user traffic or data processing. We made this by using **JMH** (the Java Microbenchmark Harness), adding the dependency in the *pom.xml* file.

5.4.1 ***Our benchmark testing.*** In order to find the classes with high computational cost we execute the following command: "*mvn package*", in order to visualize the classes that spend more time for testing. The results that we obtained are shown in Table 5. Based on these results, we applied the benchmark testing to these three classes: *HtmlEmail, ImageHtmlEmail and MultiPartEmail*. For each class we analyzed the same methods that JUnit tests have tested. The obtained results are shown in Table 6, Table 7 and Table 8. Depending on these results, we can affirm that the methods of the classes under testing took a short execution time therefore we did not apply any change.

Table 5: Execution time needs for each class during the test.

Test class name	Time (second)
DefaultAuthenticatorTest	0.025
EmailAttachmentTest	0.066
EmailLiveTest	0.268
EmailTest	0.269
EmailUtilsTest	0.01
HtmlEmailTest	1.55
ImageHtmlEmailTest	8.124
InvalidAddressTest	0.006
InvalidInternetAddressTest	0
MultiPartEmailTest	1.028
DataSourceClassPathResolverTest	0.024
DataSourceCompositeResolverTest	0.559
DataSourceFileResolverTest	0.01
DataSourceUrlResolverTest	0.755
SendWithAttachmentsTest	0.066
SimpleEmailTest	0.015
IDNEmailAddressConverterTest	0.007
MimeMessageParserTest	0.063

Table 6: Benchmark testing of HtmlEmail methods

Method name	Average Time	Min Time	Max Time
embed(final URL url, final String name)	0.001	0.001	0.001
embed(final File file)	0.002	0.002	0.002
embed(final DataSource dataSource, final String name)	0.001	0.001	0.001
embed(final File file, final String cid)	0.002	0.002	0.002
send() inherit by Email.java	0.028	0.027	0.028
buildMimeMessage()	0.003	0.003	0.004

Table 7: Benchmark testing of ImageHtmlEmail methods

Method name	Average Time	Min Time	Max Time
send() using simple text	1.302	1.227	1.391
send() using text with URL	3.030	1.749	3.721
send() using more images	3.330	1.656	4.387
buildMimeMessage()	0.042	0.037	0.051

5.5 Test case generation

In order to improve the test coverage in our project, we have used tools to automatically generate test cases on classes with lower coverage. We choose the classes based on the plot that is shown in Figure 4. Therefore the classes that we selected are: *MultiPartEmail, MimeMessageUtils, DataSourceFileResolver, DataSourceUrlResolver and HtmlEmail.* Automated tests for software are important because they verify software functionality precisely and efficiently and ensure greater test coverage than manual testing methods. In particular, we have used **EvoSuite** which generates test cases using a technique called search-based software testing. During the search process, Evosuite tracks the code coverage achieved by each test case and prioritizes the generation of new test cases that exercise previously untested code paths. The EvoSuite goal is to maximise the coverage of the class under testing then the goal function that we used is based on **line coverage** and **branch coverage**. The other EvoSuite parameters were set with default values. The GA process continues until a stop criterion, such as

Table 8: Benchmark testing of MultiPartEmail methods

Method name	Average Time	Min Time	Max Time
setMsg(final String msg)	$\approx 10^{-6}$	-	-
setMsg(final String msg) with charset	$\approx 10^{-6}$	-	-
send()	0.017	0.012	0.023
attach(final EmailAttachment attachment) with path	$\approx 10^{-4}$	-	-
attach(final EmailAttachment attachment) with url	$\approx 10^{-3}$	-	-
attach(final File file)	$\approx 10^{-4}$	-	-
addPart(final String s1, final String s2)	0.340	0.304	0.403
addPart(final MimeMultiPart)	0.371	0.291	0.416

a maximum number of iterations or a desired coverage threshold, is met. In our case, we used the default stop criterion which is **60 seconds**. For some classes under analysis, we modified the commands to autogenerate the test cases because they need the dependencies. Therefore, we modified the commands in this way:

```
#Here we indicate the class which we want to generate the
     tests for
java -jar <PATH-TO>/evosuite-1.2.0.jar -class <CLASS-FQN>
     -projectCP ./target/classes;
    <PATH-TO>/.m2/repository/javax/mail/mail/1.4/mail-1.4.jar
#Here we compile all the EvoSuite test files
javac -cp ./target/classes;<PATH-TO>/evosuite-1.2.0.jar;
    <PATH-TO>/.m2/repository/javax/mail/
    mail/1.4/mail-1.4.jar;
    ./target/dependency/junit-jupiter-5.9.1.jar;
    ./target/dependency/hamcrest-2.2.jar
         <PATH-TO-AUTOGENERATED-TEST>
#Here we run the generated tests using a JUnit launcher
java -cp evosuite-tests;
    ./target/classes;
    <PATH-TO>/.m2/repository/javax/mail/mail/1.4/mail-1.4.jar;
    <PATH-TO>/evosuite-1.2.0.jar;
    <PATH-TO>/junit-platform-console-standalone-1.9.2.jar
    org.junit.platform.console.ConsoleLauncher
         --scan-class-path
```

After EvoSuite generated the test cases, we applied some refactoring activities because some of them were wrong. For example, we fixed the test case *test14* for *MimeMessageUtils* class. This test verifies

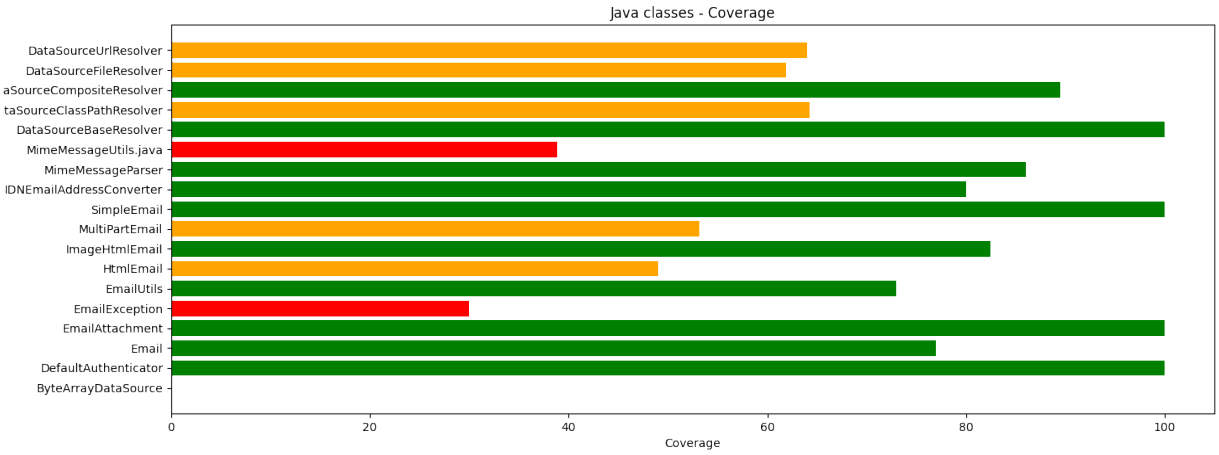


Figure 4: Class Coverage

if the Mime message has been created correctly but it created a MockFile with an incorrect name.

5.6 Vulnerability analysis

Security testing helps us to detect vulnerabilities in our software project that may be exploited by hackers to have access to sensitive data or to damage the system itself. To verify if our project has some vulnerabilities we used these tools that have different capabilities:

(1) **Find Security Bugs**: We used this tool to detect vulnerabilities in the source code of our project. Indeed, the tool analyzes only the bytecode to find vulnerabilities.
(2) **Dependency-Check**: We used this tool to detect dependency versions having known vulnerabilities. This analysis is necessary because if we use a vulnerable third-party dependency, this involved that our project has a weak spot and hackers can exploit it to damage the system. Therefore this tool conducts the analysis based on CVE vulnerabilities;
(3) **OWASP Zed Attack Proxy (ZAP):**We used this tool to detect vulnerabilities related to the Spring web application that we have developed for our project. For doing this task we have downloaded the official docker image of ZAP. After that, we have created a docker network and have connected to it the container that includes the docker image of our web application. Finally, we have executed OWASP ZAP analysis passing in the URL the ID of the web app container and the port on which is exposed the service.

5.6.1 *Find Security Bugs results.*

When we applied the analysis with FindSecBugs, we created this XML script to exclude the test files by the analysis because they will not be deployed and have no impact on the overall project security.

```
<?xml version="1.0" encoding="UTF-8"?>
<FindBugsFilter>
  <Match>
    <Class name="~.*Test?$"/>
    <Bug category="SECURITY" />
  </Match>
</FindBugsFilter>
```

The results obtained by Find Security Bugs are shown in Table 9. For the *Medium Priority Warnings* class we found two false positives and two security warnings which we can not fix. Regarding the false positives:

- The false positive of *MultiPartEmail* class regards the *attach(EmailAttachment)* method. The tool reported that the file location could be specified by user input. The instruction which caused this warning is *EmailAttachment.getPath()*. It is a false positive because the method parameter is an object which is not set by user input and its attribute `"path"` is used only in test classes, and it has a precondition over it.
- The false positive of *Email* class regards the *setMailSessionFromJNDI(String)* method. The tool reported that the use of *javax.naming.Context.lookup(String)* can be vulnerable to LDAP injection. We classified it as a false positive because the method parameter is already validated.

Regarding the warnings that we can't fix:

- In the *MultiPartEmail* class, the warning referred to *attach(URL, String, String, String)* method. The tool reported that the parameter `"url"` could be used by an attacker to expose internal services and the filesystem. We do not fix it because the url is defined by two other methods of the same class and we can not define a white list or validate if the beginning of the URL is part of a white list as suggested by the tool;
- In the *HtmlEmail* class, the warning referred to the *embed(URL, String)* method. The tool reported that the parameter `"url"` could be used by an attacker to expose internal

services and the filesystem. We do not fix it because the url is defined by another method of the same class and we can not define a white list or validate if the beginning of the URL is part of a white list as suggested by the tool.

Table 9: Find Security Bugs results

Metric	Total	Density
High Priority Warnings	-	0
Medium Priority Warnings	5	0.25

The last remaining security warning regards the use of *java.util.Random* because it generates a predictable value, therefore we replaced it with *java.security.SecureRandom*.

5.6.2 *Dependency-Check results*.

We executed the tool and obtained that the third-party dependencies versions, which our project uses, are not vulnerable.

6 CONCLUSIONS

After we applied all the refactoring activities, we reran the SonarCloud, EcoCode, Codecov, and FindSecBugs analysis and found no additional issues. In particular, we noticed an improvement in the coverage by +3.37% in CodeCov, resulting in a total coverage of 68.99%. SonarCloud also acknowledged the improvement (see Figure 5).

Figure 5: SonarCloud report

EcoCode reported 0 eco-code smells (see Figure 6).

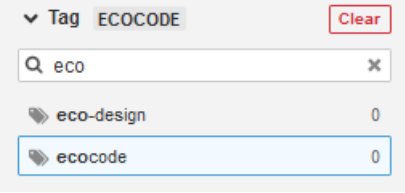
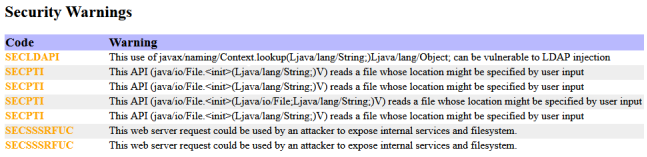


Figure 6: EcoCode report

With FindSecBugs analysis (see Figure 7) on the refactored project, we encountered the same false positives as the preliminary analysis, except one which we classified as a false positive because the tool reported that the parameter could be used by an attacker to expose internal services and the file system, but in fact, the method has a precondition on the parameter. The method is: `DataSourceFileResolver.resolve(String, bool)`.



Security Warnings

Code	Warning
SECLDAPI	This use of javax/naming/Context.lookup(Ljava/lang/String;)Ljava/lang/Object; can be vulnerable to LDAP injection
SECPTI	This API (java/io/File.<init>(Ljava/lang/String;)V) reads a file whose location might be specified by user input
SECPTI	This API (java/io/File.<init>(Ljava/lang/String;)V) reads a file whose location might be specified by user input
SECPTI	This API (java/io/File.<init>(Ljava/io/File;Ljava/lang/String;)V) reads a file whose location might be specified by user input
SECPTI	This API (java/io/File.<init>(Ljava/lang/String;)V) reads a file whose location might be specified by user input
SECSSSRFUC	This web server request could be used by an attacker to expose internal services and filesystem.
SECSSSRFUC	This web server request could be used by an attacker to expose internal services and filesystem.

Figure 7: FindSecBug report

Finally, we executed OWASP ZAP (Zed Attack Proxy) on our web application and found no vulnerabilities. Result: **FAIL-NEW: 0 FAIL-INPROG: 0 WARN-NEW: 10 WARN-INPROG: 0 INFO: 0 IGNORE: 0 PASS: 50**