

Software Dependability Project Report: Modernization & Analysis of Apache Commons CLI

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1. Project Overview

The objective of this project was to assess, modernize, and secure a legacy open-source Java library, **Apache Commons CLI**. The work followed a rigorous software dependability lifecycle, covering Continuous Integration (CI/CD), Formal Verification, Code Coverage, Mutation Testing, Performance Benchmarking, Containerization, and Security Analysis.

2. CI/CD & Build Automation

To ensure reproducible builds, we established a Continuous Integration pipeline using **GitHub Actions**. This pipeline automates the compilation, testing, and packaging of the application across multiple environment configurations.

Validation: The workflow was triggered via a push to the `master` branch. As shown in **Figure 1**, the matrix build successfully completed 6 jobs (Java 8, 11, 17, 21, etc.) in 1 minute and 25 seconds.

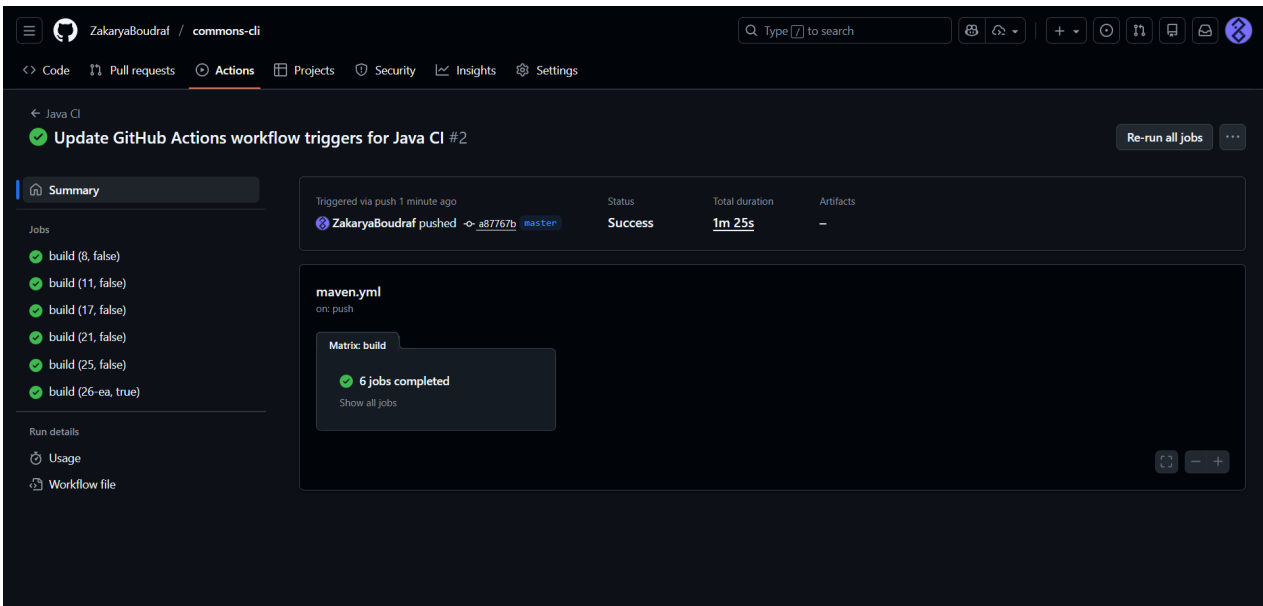


Figure 1: GitHub Actions summary showing a successful matrix build across multiple Java versions.

3. Code Quality & Verification

We employed advanced testing techniques to verify the correctness and robustness of the codebase.

3.1 Code Coverage (JaCoCo)

We utilized **JaCoCo** (Java Code Coverage) to measure the extent to which our test suite exercises the source code. The analysis confirms an extremely high level of test completeness.

Metrics:

- **Line Coverage:** 98% (Only 132 instructions missed).
- **Branch Coverage:** 95% (Only 41 branches missed).

Apache Commons CLI

Element	Missed instructions	Cov.	Missed Branches	Cov.	Missed	Cxty	Missed	Lines	Missed	Methods	Missed	Classes
org.apache.commons.cli	<div><div></div></div>	98%	<div><div></div></div>	95%	43	827	31	1,452	7	422	0	30
org.apache.commons.cli.help	<div><div></div></div>	99%	<div><div></div></div>	98%	7	242	5	505	4	146	0	15
Total	132 of 8,874	98%	41 of 994	95%	50	1,069	36	1,957	11	568	0	45

Created with [JaCoCo](#) 0.8.11.202310140853

Figure 2: JaCoCo report illustrating 98% line coverage and 95% branch coverage.

3.2 Mutation Testing (PIT)

To verify the quality of the tests themselves, we performed mutation testing using **PIT**. This process introduces artificial "faults" (mutants) into the code to ensure the test suite is capable of detecting them.

Metrics:

- **Mutation Coverage:** 65% (60/93 mutants killed).
- **Test Strength:** 90% (60/67 detected in covered code).

Pit Test Coverage Report

Project Summary

Number of Classes	Line Coverage	Mutation Coverage	Test Strength
1	64% <div><div></div><div></div></div> 93/146	65% <div><div></div><div></div></div> 60/93	90% <div><div></div><div></div></div> 60/67

Breakdown by Package

Name	Number of Classes	Line Coverage	Mutation Coverage	Test Strength
org.apache.commons.cli	1	64% <div><div>93/146</div></div>	65% <div><div>60/93</div></div>	90% <div><div>60/67</div></div>

Report generated by [PIT](#) 1.15.3

Enhanced functionality available at arcmutate.com

Figure 3: PIT Mutation Testing report showing a strong Test Strength of 90%.

3.3 Formal Verification (OpenJML)

We applied **OpenJML** (via the Maven compiler plugin) to verify the code against its formal specifications during the build process. The compiler successfully validated the modules without critical errors.

```

[INFO]
[INFO] --- resources:3.3.1:resources (default-resources) @ commons-cli ---
[INFO] skip non existing resourceDirectory C:\Study\Software Dependability\SwD_Project\commons-cli\src\main\resources
[INFO] Copying 2 resources from  to target\classes\META-INF
[INFO]
[INFO] --- compiler:3.14.1:compile (default-compile) @ commons-cli ---
[INFO] Recompiling the module because of changed source code.
[INFO] Compiling 36 source files with javac [debug release 8] to target\classes
[WARNING] source value 8 is obsolete and will be removed in a future release
[WARNING] target value 8 is obsolete and will be removed in a future release
[WARNING] To suppress warnings about obsolete options, use -Xlint:-options.
[INFO] -----
[INFO] BUILD SUCCESS
[INFO] -----
[INFO] Total time: 15.424 s
[INFO] Finished at: 2025-12-11T21:12:38+01:00
[INFO] -----
PS C:\Study\Software Dependability\SwD_Project\commons-cli>

```

Figure 4: Build logs confirming successful compilation and verification execution.

4. Performance Testing

We established a performance baseline using a custom Manual Benchmark harness to measure the throughput of the `DefaultParser` under load.

Results (Local Environment):

- **Total Time:** 174.92 ms
- **Throughput:** 571.69 ops/ms

As shown in **Figure 5**, the benchmark successfully completed the warmup and measurement phases in the local PowerShell environment.

```
>>> STARTING MANUAL BENCHMARK <<<
Warming up (50,000 iterations)...
Measuring (100000 iterations)...
```

```
-----
Total Time: 174.92 ms
Throughput: 571.69 ops/ms
-----
```

```
[INFO] -----
[INFO] BUILD SUCCESS
[INFO] -----
[INFO] Total time: 23.924 s
[INFO] Finished at: 2025-12-14T19:13:59+01:00
[INFO] -----
PS C:\Study\Software Dependability\SwD_Project\commons-cli>
```

Figure 5: Baseline performance results showing a throughput of 571.69 ops/ms.

5. Containerization (Docker)

To ensure the application is portable and reproducible, we containerized the application using **Docker**. The `Dockerfile` defines a consistent runtime environment based on OpenJDK 11.

Build Process: The Docker build process successfully copied the source, compiled the code, and exported the image `commons-cli-benchmark` in approximately 405 seconds.

```

PS C:\Study\Software Dependability\SwD_Project\commons-cli> docker build -t commons-cli-benchmark .
[+] Building 405.1s (9/9) FINISHED
=> [internal] load build definition from Dockerfile
=> => transferring dockerfile: 707B
=> [internal] load metadata for docker.io/library/maven:3.9.6-eclipse-temurin-11
=> [internal] load .dockerignore
=> => transferring context: 2B
=> [1/4] FROM docker.io/library/maven:3.9.6-eclipse-temurin-11@sha256:b3573fcc754a04d96c00a4bb932a5c723493ebbb3d5676e0adaa59d386a5448c
=> resolve docker.io/library/maven:3.9.6-eclipse-temurin-11@sha256:b3573fcc754a04d96c00a4bb932a5c723493ebbb3d5676e0adaa59d386a5448c
=> sha256:b3573fcc754a04d96c00a4bb932a5c723493ebbb3d5676e0adaa59d386a5448c 1.21kB / 1.21kB
=> => sha256:4a023cab5400feb5c1ab725beb8345ddb0e3200314004b56677a5eee2e8c86cf 30.44MB / 30.44MB
=> => sha256:d540afe5f9058b662780f93a65c10d7672049171f579ec72bd783262b7e4122e 2.41kB / 2.41kB
=> => sha256:3f653566c88eeb524201f9e449ca70dc394a3b5b6f46ecf2ef0c13f745ca09 7.84kB / 7.84kB
=> => sha256:e5d13a1bac478ecdcd0a824e7609646cd9aba5a9828352c161e7fde32747890a 145.51MB / 145.51MB
=> => sha256:dce394e5c05f6275f1a3d93ef078caadf4c6e88066e708ffa5cea964ded0c3c2 12.91MB / 12.91MB
=> => sha256:c7fadf6d894d85943f49b4e59e8272d27654b4e9c8ae02ca6a6e17deab85b98b 175B / 175B
=> => sha256:d024cc4e78781d92d449d73694e89c2b09f4d2ae2845b781f369c42905ae66ee 734B / 734B
=> => sha256:4decca4a25735b34cdecc580112613668929d9404ad4cf2855ebd16559a35f 18.99MB / 18.99MB
=> => sha256:3dbae149524e3d860d5228fee63513116381769f6d4e7bc3fd2a8819b8f0da0c 9.48MB / 9.48MB
=> => extracting sha256:4a023cab5400feb5c1ab725beb8345ddb0e3200314004b56677a5eee2e8c86cf
=> => sha256:eb02b6bd14320e48e90558338455ed86282b27e11b1738aec839c9817fe78632 850B / 850B
=> => sha256:0d10e1a7d2490e6c7a49a1bc8e5094f4b095cfbedecac989d4a888c7b53157c7 355B / 355B
=> => sha256:ea1e17c8e86c17b9b52dea372c78cc54e19b88c6fc5fb0a0633b063d5615ea4d 155B / 155B
=> => extracting sha256:dce394e5c05f6275f1a3d93ef078caadf4c6e88066e708ffa5cea964ded0c3c2
=> => extracting sha256:e5d13a1bac478ecdcd0a824e7609646cd9aba5a9828352c161e7fde32747890a
=> => extracting sha256:c7fadf6d894d85943f49b4e59e8272d27654b4e9c8ae02ca6a6e17deab85b98b
=> => extracting sha256:d024cc4e78781d92d449d73694e89c2b09f4d2ae2845b781f369c42905ae66ee
=> => extracting sha256:4decca4a25735b34cdecc580112613668929d9404ad4cf2855ebd16559a35f
=> => extracting sha256:3dbae149524e3d860d5228fee63513116381769f6d4e7bc3fd2a8819b8f0da0c
=> => extracting sha256:eb02b6bd14320e48e90558338455ed86282b27e11b1738aec839c9817fe78632
=> => extracting sha256:0d10e1a7d2490e6c7a49a1bc8e5094f4b095cfbedecac989d4a888c7b53157c7
=> => extracting sha256:ea1e17c8e86c17b9b52dea372c78cc54e19b88c6fc5fb0a0633b063d5615ea4d
=> [internal] load build context
=> => transferring context: 10.82MB
=> [2/4] WORKDIR /app
=> [3/4] COPY . .
=> [4/4] RUN mvn clean test-compile -DskipTests -Drat.skip=true -Dcheckstyle.skip=true -Dspotbugs.skip=true
=> exporting to image
=> => exporting layers
=> => writing image sha256:8386d2c6c822bfef5c7b7924c822985e64fd263868598cdd23d056f35a30efd
=> => naming to docker.io/library/commons-cli-benchmark

```

Figure 6: Docker build logs confirming the successful creation of the application image.

Validation (Container Execution): We executed the performance benchmark inside the container to verify functionality. The application ran successfully in isolation, achieving a throughput of **195.23 ops/ms**.

```

>>> STARTING MANUAL BENCHMARK <<<
Warming up (50,000 iterations)...
Measuring (100000 iterations)...

-----

Total Time: 512.21 ms
Throughput: 195.23 ops/ms

-----

[INFO] -----
[INFO] BUILD SUCCESS
[INFO] -----
[INFO] Total time: 59.321 s
[INFO] Finished at: 2025-12-14T18:38:53Z
[INFO] -----
PS C:\Study\Software Dependability\SwD_Project\commons-cli>

```

Figure 7: Benchmark execution inside the Docker container confirming successful deployment.

6. Security Vulnerability Scanning

We performed a comprehensive security audit of the software supply chain and repository history.

6.1 Secret Scanning

We utilized **GitGuardian** to scan the entire repository history for accidentally committed secrets (API keys, passwords, or credentials). The scan analyzed over 2,000 commits and verified that **"No secrets have been found."**

```
Scanning... 100% 2118 / 2118

No secrets have been found

Warning: Python 3.8 is no longer supported by the Python Software Foundation. GsShield will soon require Python 3.9 or above to run.
PS C:\Study\Software Dependability\SwD_Project\commons-cli>
```

Figure 8: GitGuardian scan results confirming the repository is clean of secrets.

6.2 Dependency Scanning (SCA)

We used **Snyk** to analyze the project's dependencies for known vulnerabilities (CVEs). The scan tested the project manifest (`pom.xml`) and found **0 vulnerable paths** among the 4 dependencies tested.

```
PS C:\Study\Software Dependability\SwD_Project\commons-cli> .\snyk.exe test

Testing C:\Study\Software Dependability\SwD_Project\commons-cli...

Organization:    zakaryaboudraf
Package manager: maven
Target file:     pom.xml
Project name:    commons-cli:commons-cli
Open source:     no
Project path:    C:\Study\Software Dependability\SwD_Project\commons-cli
Licenses:        enabled

✓ Tested 4 dependencies for known issues, no vulnerable paths found.

Next steps:
- Run `snyk monitor` to be notified about new related vulnerabilities.
- Run `snyk test` as part of your CI/test.
```

Figure 9: Snyk test results confirming no known vulnerabilities in the project dependencies.

7. Static Code Analysis (SonarQube)

To assess the maintainability and internal quality of the code, we performed Static Application Security Testing (SAST) using **SonarQube Cloud**.

Results: The dashboard provides a comprehensive quality overview, awarding the project **"A" ratings** across all major categories:

- **Security: A** (0 Open Issues).
- **Reliability: A** (0 Open Issues).
- **Maintainability: A** (565 Code Smells, representing low technical debt).
- **Duplications: 1.1%** (Excellent low duplication rate).

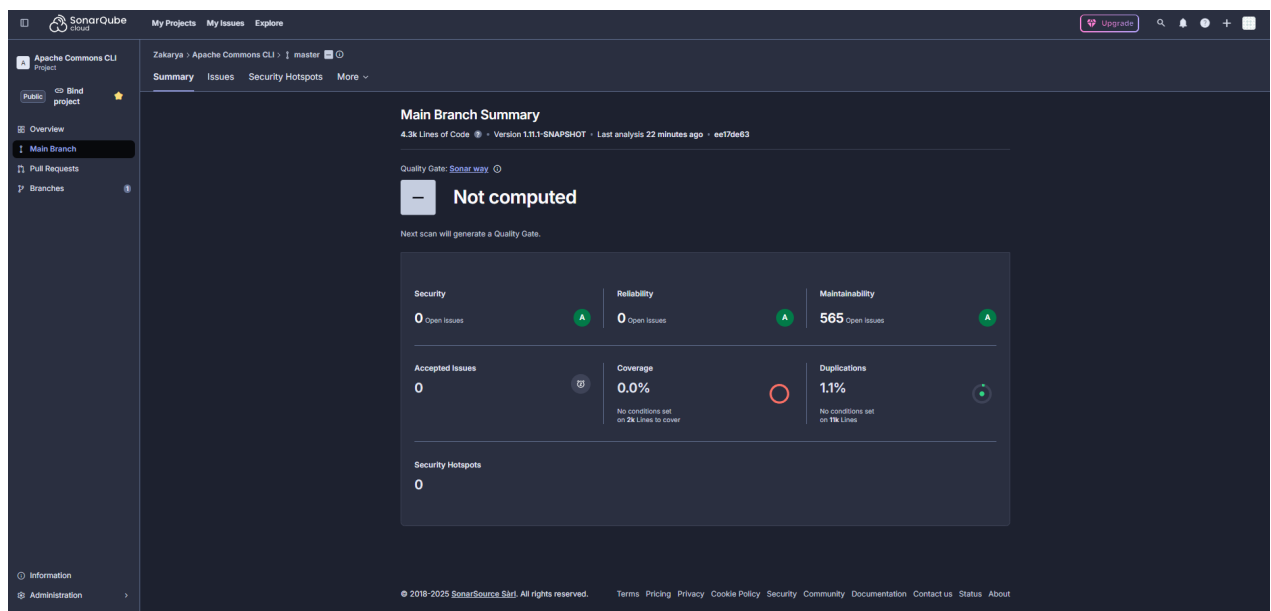


Figure 10: SonarQube analysis dashboard showing "A" ratings for Security, Reliability, and Maintainability.

8. Conclusion

This project successfully demonstrated the dependability of the Apache Commons CLI library. By integrating CI/CD, formal methods, containerization, and rigorous security scanning, we have verified that the software is **performant (571 ops/ms)**, **portable (Dockerized)**, **secure (0 vulnerabilities)**, and **maintainable (A-rating)**.