ANALYSIS OF TEST SMELL IMPACT ON TEST CODE QUALITY

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AGENDA

MOTIVATION

- Software testing is a fundamental part of the software development process.
  - Test cases play a crucial role in the early detection of software bugs during the software development process.
- Despite its importance, test smells are often existing in test codes.
  - Test smells in test code has the potential to affect the overall quality of test suites and the quality of the production code.

MOTIVATION

- Developers and testers may unintentionally introduce these smells into the test code.
  - Not only because of lack of skills, but also due to pressures of deadlines, lack of awareness, or insufficient tool support.
- It is used modern test smell detection tools-JNose and TestSmellDetector tools-to get information for prevalence and co-occurrence of different smells.

OBJECTIVE

- Purpose of our study is to answer the following research questions (RQs):
  - What are the most and least frequently detected test smells in test codes?
  - What is the total number of test smells detected by each tool and their distribution in the test code files?
  - Is there a considerable co-occurrence between the test smells detected by JNose and TestSmellDetector tools?

RELATED WORK

- Modern studies are going in the direction of discovering, defining, and eliminating test smells, and explaining their origins and influence on the overall program quality.

RELATED WORK

- In a study conducted by Silva Junior et al., researchers investigated the level of awareness regarding the unintentional inclusion of smells in test code development.
    - A survey contains 60 chosen professionals from different organizations.
    - Investigating the frequency and situations in which they encounter smells.
    - Particularly 14 types of test smells are used.

RELATED WORK

- In another study related to the severity of test smells by Campos et al.,
  - Targeting a set of tests that cause problematic consequences.
  - Mentioning the developers' point of view on issues of tests.
  - Eight test smells are used in this study (Assertion Roulette (AR), Empty Test (EpT), Unknown Test (UT), Eager Test (ET), Lazy Test (LT), Constructor Initialization (CI), Sensitive Equality (SE), and Redundant Assertion (RA)).

RELATED WORK

- In a similar study by Davide Spadini et al., severity thresholds for test smells are investigated.
  - 1489 java projects from Apache and Eclipse ecosystems and TestSmellDetector tool are used,
  - 4 test smells-Assertion Roulette (AR), Eager Test (ET), Verbose Test (VT), and Conditional Test Logic (CTL)- are observed as higher thresholds than others.

RELATED WORK

- Another study by Michele Tufano et al. presented
  - A survey contains 19 developers.
  - Purpose of the survey is to find out how they rated test smells as design issues.
  - A huge empirical study based on commit history of 152 open-source projects
  - Focusing on when test smells are introduced, how long they last and their relationship.

TOOL INFRASTRUCTURE – JNOSE TOOL

- The JNose Test tool enables testers
  - To review the past versions of the software projects
  - To find the test coverage and the test smells that often affect the code quality.

TOOL INFRASTRUCTURE – JNOSE TOOL

- Figure 1: Schematic overview of the JNose Test tool and its main features
- (i) Data Input: This part receives the input for the tool execution, such as test smell types of list, analysis mode and the project for analysis.
- (ii) Project Analysis: This component presents the analysis of the program by choosing the analysis mode.
- (iii) Data Output: By this component, the status of the execution is being rendered and the .csv file containing the results of the analysis is generated.

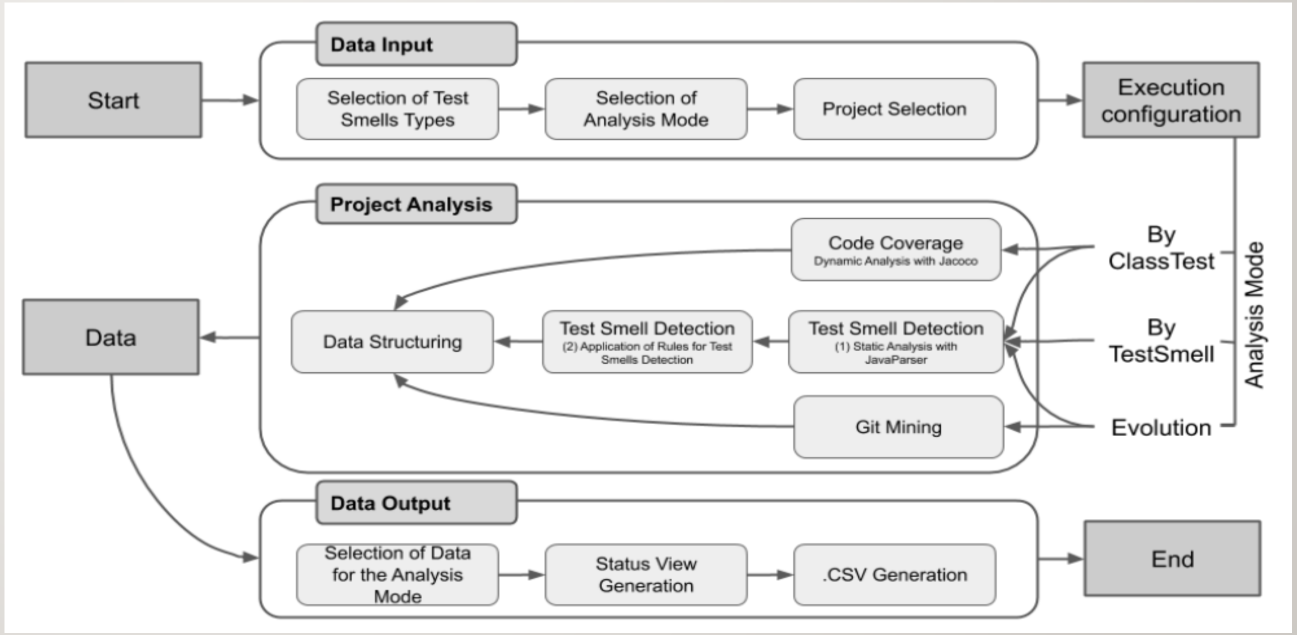


Figure 1: High-level architecture of JNose tool

TOOL INFRASTRUCTURE – JNOSE TOOL

- The JNose Tool offers the capability to detect and analyze smells in various ways.
  - Firstly, it can detect smells in a specific test class using the TestClass method, which provides information about the quantity of each type of smell detected in the test class.
  - Secondly, it can detect smells across multiple project versions using the Evolution method, which provides information about the authors and timestamps of the test smell's insertion in the test code.
  - Lastly, the detection can be used to identify the precise location of a test smell using the TestSmell method, which returns the method location of the smell for the purpose of analyzing the quality of the test code.

TOOL INFRASTRUCTURE – JNOSE TOOL

- In accordance with the GNU General Public License, the JNose Test tool is licensed. The software tool is developed as a Java project and consists of four packages:
  - (i) core, which is responsible for detecting test smells and coverage metrics;
  - (ii) page, which is responsible for displaying web pages and their content;
  - (iii) dto, which includes the classes used in data transfer (Data Transfer Object);
  - (iv) util, which is responsible for identifying tests and production classes and saving results into.csv files

TOOL INFRASTRUCTURE – TESTSMELLDETECTOR TOOL

- TestSmellDetector tool is a Java jar file that is open-source.
- The TestSmellDetector tool provides a detailed list of detected smells, with their respective definitions and detection algorithms.
  - TestSmellDetector tool presently identifies 19 test smells that are applicable to all Java-based systems.
- The implementation of TestSmellDetector tool as a self-contained executable file, as a plugin, eliminates the need for users to own a dedicated Integrated Development Environment (IDE) on their system for identifying smells in their test code.

TOOL INFRASTRUCTURE – TESTSMELLDETECTOR TOOL

- Figure 2 illustrates an overview of the architectural design of the TestSmellDetector tool. The project structure is used in ① and ② to identify the test and production files. TestSmellDetector tool determines whether test smells are present in the test files in ③ and ④. The test smell detection process findings are saved in ⑤.

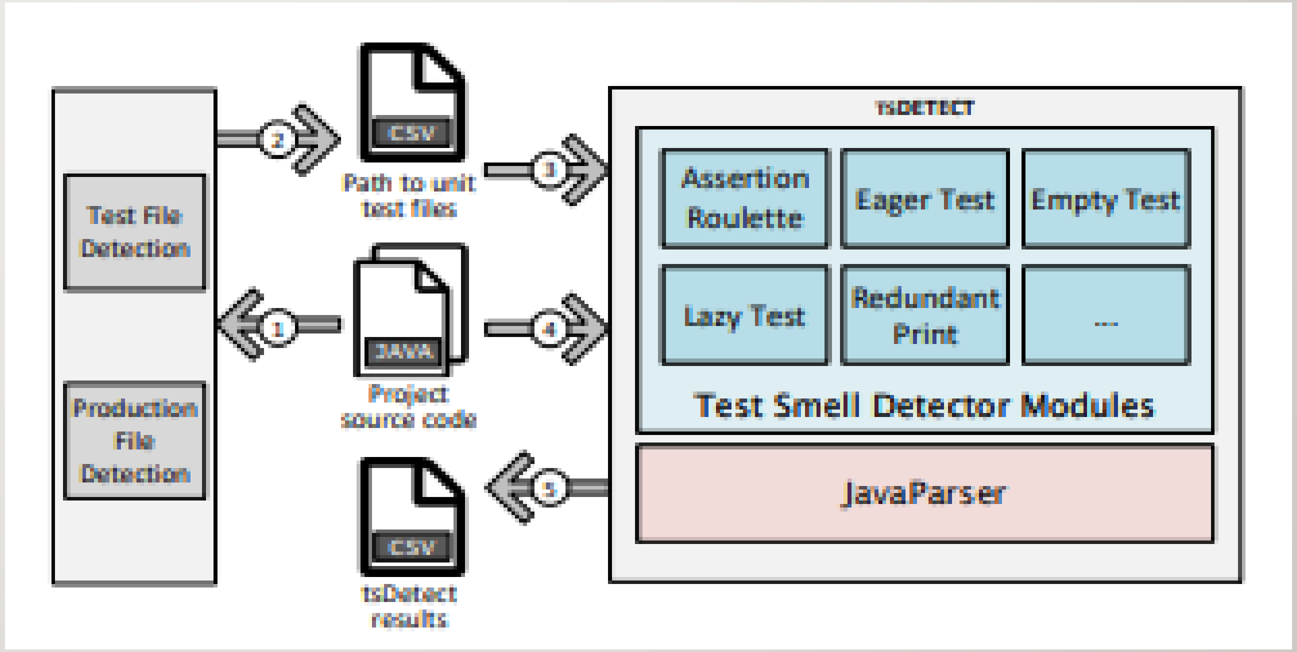
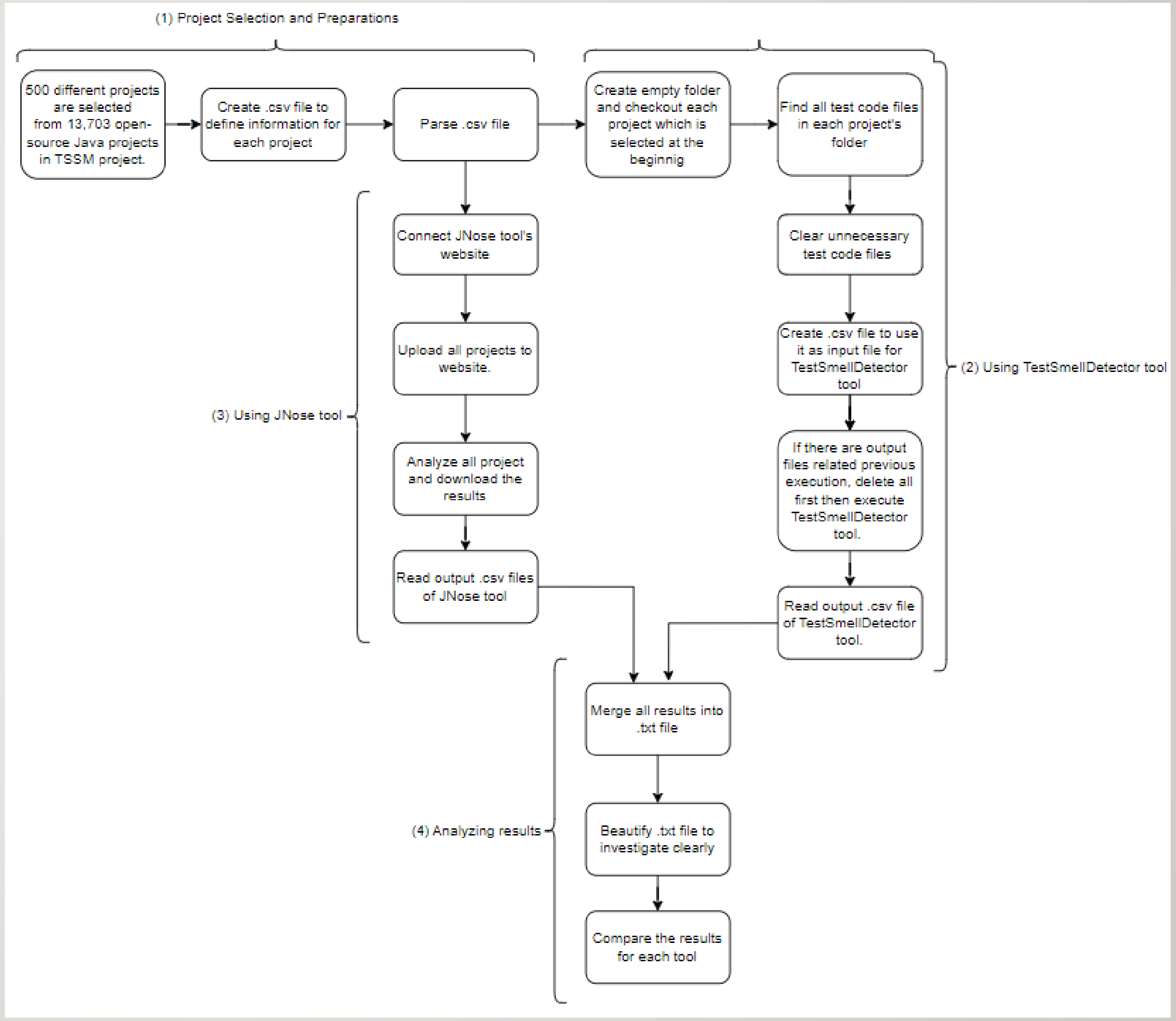


Figure 2: High-level architecture of TestSmellDetector tool

CASE STUDY

- Figure 3 shows an overview of our study. Mainly in this study, there are four parts to get results to compare and to answer our research questions.



(1) Project Selection and Preparations
500 different projects are selected from 13,703 open-source Java projects in TSSM project.
Create .csv file to define information for each project
Parse .csv file
Create empty folder and checkout each project which is selected at the beginnig
Find all test code files in each project's folder
Clear unnecessary test code files
Create .csv file to use it as input file for TestSmellDetector tool
If there are output files related previous execution, delete all first then execute TestSmellDetector tool.
Read output .csv file of TestSmellDetector tool.
(2) Using TestSmellDetector tool
(3) Using JNose tool
Connect JNose tool's website
Upload all projects to website.
Analyze all project and download the results
Read output .csv files of JNose tool
(4) Analyzing results
Merge all results into .txt file
Beautify .txt file to investigate clearly
Compare the results for each tool

Figure 3: High-level architecture of our study

CASE STUDY – PROJECT SELECTION

- Project Selection:
  - These procedures led to the collection of data from 13,703 open-source Java projects
  - 500 distinct projects are randomly chosen from this collection of open-source Java projects.
  - These projects work with the Test Smell Detector Tool as well as the JNose Tool.

CASE STUDY - IMPLEMENTATION OF AUTOMATED SCRIPTS:

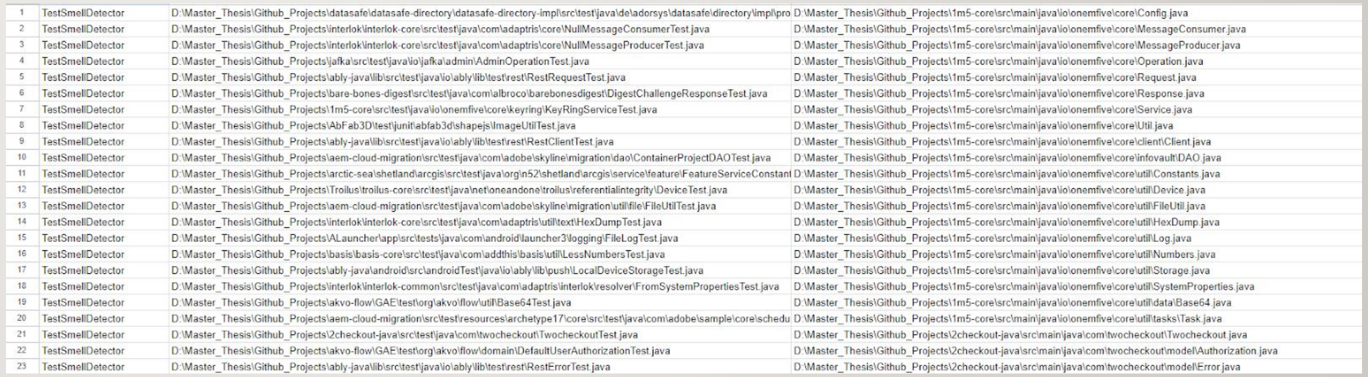
- Implementation of Automated Scripts:
  - Four fundamental Python files were implemented.
  - All functions' explanations are present on the GitHub project https://github.com/ismailcebeci/Master_Thesis_Project

CASE STUDY - IMPLEMENTATION OF AUTOMATED SCRIPTS:

- preparation_for_using_tools.py
  - def read_csv_and_extract_info(file_path) function: To pick out necessary column names from input .csv file.
  - def create_folders(base_path, folder_names) function: The create_folders function creates empty folder with using "git_project_modified_name" list
  - clone_git_projects(base_path, git_clone_url, git_project_modified_name) function: To clone GitHub projects into created empty folders one by one.
  - find_files_for_test_and_source_codes_by_partial_name(folder_path, partial_name) function: To test files and their associated source files within GitHub project folders.

CASE STUDY - IMPLEMENTATION OF AUTOMATED SCRIPTS:

- remove_java_test_and_source_files_from_list(test_file_paths,source_file_paths) function: To removes the files, where the lines' sole content are comments.
- write_lists_to_csv(constant_name,list1, list2, output_folder, file_name) function: The main role of this method is the creation of a structured CSV file as shown Figure 4, which is originally named with output.csv and it is specifically designed to meet the given inputs of the TestSmellDetector application.



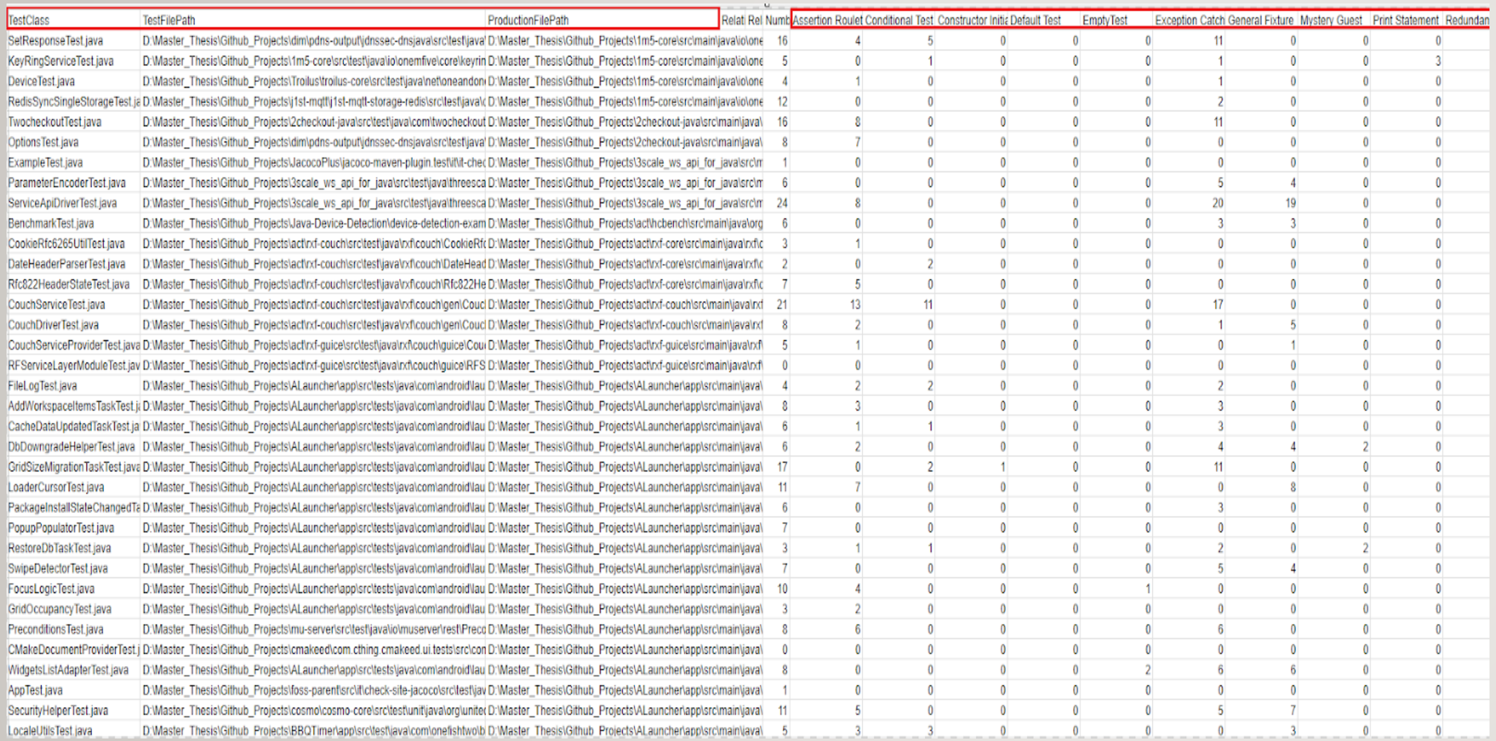
1	TestSmellDetector	D:\Master_Thesis\Github_Projects\datasafe\datasafe-directory\datasafe-directory-impl\src\test\java\de\adorsys\datasafe\directory\impl\pro	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\Config.java
2	TestSmellDetector	D:\Master_Thesis\Github_Projects\interlok\interlok-core\src\test\java\com\adaptris\core\NullMessageConsumerTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\MessageConsumer.java
3	TestSmellDetector	D:\Master_Thesis\Github_Projects\interlok\interlok-core\src\test\java\com\adaptris\core\NullMessageProducerTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\MessageProducer.java
4	TestSmellDetector	D:\Master_Thesis\Github_Projects\jafka\src\test\java\io\jafka\admin\AdminOperationTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\Operation.java
5	TestSmellDetector	D:\Master_Thesis\Github_Projects\ably-java\lib\src\test\java\io\ably\lib\test\rest\RestRequestTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\Request.java
6	TestSmellDetector	D:\Master_Thesis\Github_Projects\bare-bones-digest\src\test\java\com\albroco\barebonesdigest\DigestChallengeResponseTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\Response.java
7	TestSmellDetector	D:\Master_Thesis\Github_Projects\1m5-core\src\test\java\io\onemfive\core\keyring\KeyRingServiceTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\Service.java
8	TestSmellDetector	D:\Master_Thesis\Github_Projects\AbFab3D\test\junit\abfab3d\shapejs\ImageUtilTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\Util.java
9	TestSmellDetector	D:\Master_Thesis\Github_Projects\ably-java\lib\src\test\java\io\ably\lib\test\rest\RestClientTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\client\Client.java
10	TestSmellDetector	D:\Master_Thesis\Github_Projects\aem-cloud-migration\src\test\java\com\adobe\skyline\migration\dao\ContainerProjectDAOTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\infovault\DAO.java
11	TestSmellDetector	D:\Master_Thesis\Github_Projects\arctic-sea\shetland\arcgis\src\test\java\org\n52\shetland\arcgis\service\feature\FeatureServiceConstant	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\util\Constants.java
12	TestSmellDetector	D:\Master_Thesis\Github_Projects\Troilus\troilus-core\src\test\java\net\oneandone\troilus\referentialintegrity\DeviceTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\util\Device.java
13	TestSmellDetector	D:\Master_Thesis\Github_Projects\aem-cloud-migration\src\test\java\com\adobe\skyline\migration\util\file\FileUtilTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\util\FileUtil.java
14	TestSmellDetector	D:\Master_Thesis\Github_Projects\interlok\interlok-core\src\test\java\com\adaptris\util\text\HexDumpTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\util\HexDump.java
15	TestSmellDetector	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\launcher3\logging\FileLogTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\util\Log.java
16	TestSmellDetector	D:\Master_Thesis\Github_Projects\basis\basis-core\src\test\java\com\addthis\basis\util\LessNumbersTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\util\Numbers.java
17	TestSmellDetector	D:\Master_Thesis\Github_Projects\ably-java\android\src\androidTest\java\io\ably\lib\push\LocalDeviceStorageTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\util\Storage.java
18	TestSmellDetector	D:\Master_Thesis\Github_Projects\interlok\interlok-common\src\test\java\com\adaptris\interlok\resolver\FromSystemPropertiesTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\util\SystemProperties.java
19	TestSmellDetector	D:\Master_Thesis\Github_Projects\akvo-flow\GAE\test\org\akvo\flow\util\Base64Test.java	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\util\data\Base64.java
20	TestSmellDetector	D:\Master_Thesis\Github_Projects\aem-cloud-migration\src\test\resources\archetype17\core\src\test\java\com\adobe\sample\core\schedu	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\onemfive\core\util\tasks\Task.java
21	TestSmellDetector	D:\Master_Thesis\Github_Projects\2checkout-java\src\test\java\com\twocheckout\TwocheckoutTest.java	D:\Master_Thesis\Github_Projects\2checkout-java\src\main\java\com\twocheckout\Twocheckout.java
22	TestSmellDetector	D:\Master_Thesis\Github_Projects\akvo-flow\GAE\test\org\akvo\flow\domain\DefaultUserAuthorizationTest.java	D:\Master_Thesis\Github_Projects\2checkout-java\src\main\java\com\twocheckout\model\Authorization.java
23	TestSmellDetector	D:\Master_Thesis\Github_Projects\ably-java\lib\src\test\java\io\ably\lib\test\rest\RestErrorTest.java	D:\Master_Thesis\Github_Projects\2checkout-java\src\main\java\com\twocheckout\model\Error.java

Figure 4: Output csv file of write_lists_to_csv function

CASE STUDY - IMPLEMENTATION OF AUTOMATED SCRIPTS:

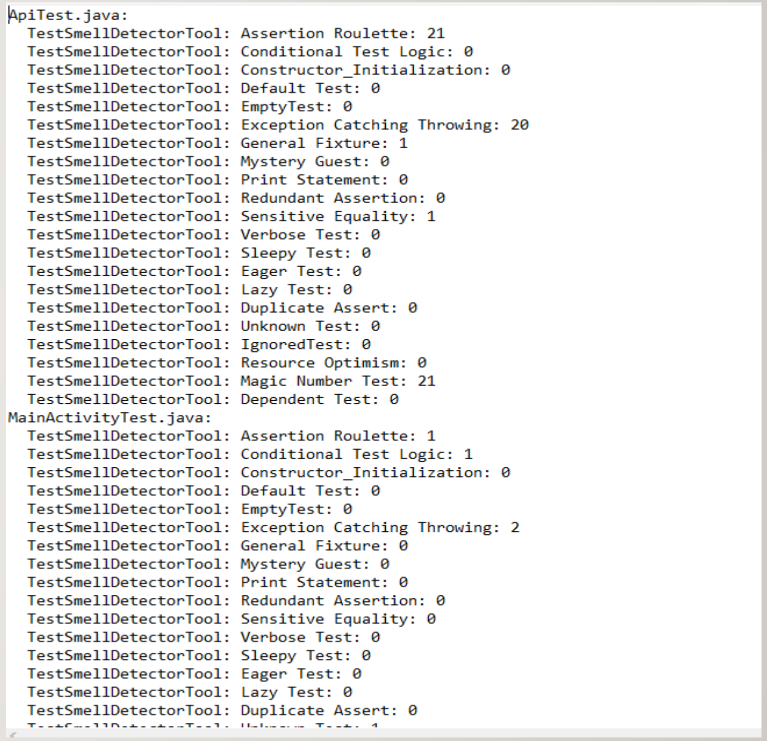
- using_test_smell_tools.py
  - execute_tool(tool_path, file_name) function: To execute TestSmellDetector Tool based on the command 'java -jar {tool_path} {file_name}' with 'output.csv' as a file input. It also produces a detailed output file, named "output_TestSmellDetection_*.csv"
  - delete_files_by_pattern(folder_path, filename_pattern) function: It is designed to implement the procedure for deleting files left over from past executions.
  - read_csv_files_by_pattern(folder_path,filename_pattern) function: To read results clearly going through the CSV file "output_TestSmellDetection_*.csv" as shown in Figure 5. After reading, Output_of_TestSmellDetector_Tool.txt file is saved as Figure 6.

CASE STUDY - IMPLEMENTATION OF AUTOMATED SCRIPTS:



TestClass	TestFilePath	ProductionFilePath	Relat	Rel	Numb	Assertion Roulet	Conditional Test	Constructor Initia	Default Test	EmptyTest	Exception Catch	General Fixture	Mystery Guest	Print Statement	Redundan
SetResponseTest.java	D:\Master_Thesis\Github_Projects\dim\pdns-output\jdnssec-dnsjava\src\test\java'	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\one			16	4	5	0	0	0	11	0	0	0	
KeyRingServiceTest.java	D:\Master_Thesis\Github_Projects\1m5-core\src\test\java\io\onemfive\core\keyrin	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\one			5	0	1	0	0	0	1	0	0	3	
DeviceTest.java	D:\Master_Thesis\Github_Projects\Troilus\troilus-core\src\test\java\net\oneandon	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\one			4	1	0	0	0	0	1	0	0	0	
RedisSyncSingleStorageTest.ja	D:\Master_Thesis\Github_Projects\j1st-mqtt\j1st-mqtt-storage-redis\src\test\java\	D:\Master_Thesis\Github_Projects\1m5-core\src\main\java\io\one			12	0	0	0	0	0	2	0	0	0	
TwocheckoutTest.java	D:\Master_Thesis\Github_Projects\2checkout-java\src\test\java\com\twocheckout	D:\Master_Thesis\Github_Projects\2checkout-java\src\main\java\			16	8	0	0	0	0	11	0	0	0	
OptionsTest.java	D:\Master_Thesis\Github_Projects\dim\pdns-output\jdnssec-dnsjava\src\test\java'	D:\Master_Thesis\Github_Projects\2checkout-java\src\main\java\			8	7	0	0	0	0	0	0	0	0	
ExampleTest.java	D:\Master_Thesis\Github_Projects\JacocoPlus\jacoco-maven-plugin.test\it\it-chec	D:\Master_Thesis\Github_Projects\3scale_ws_api_for_java\src\m			1	0	0	0	0	0	0	0	0	0	
ParameterEncoderTest.java	D:\Master_Thesis\Github_Projects\3scale_ws_api_for_java\src\test\java\threesca	D:\Master_Thesis\Github_Projects\3scale_ws_api_for_java\src\m			6	0	0	0	0	0	5	4	0	0	
ServiceApiDriverTest.java	D:\Master_Thesis\Github_Projects\3scale_ws_api_for_java\src\test\java\threesca	D:\Master_Thesis\Github_Projects\3scale_ws_api_for_java\src\m			24	8	0	0	0	0	20	19	0	0	
BenchmarkTest.java	D:\Master_Thesis\Github_Projects\Java-Device-Detection\device-detection-exam	D:\Master_Thesis\Github_Projects\act\hcbench\src\main\java\org			6	0	0	0	0	0	3	3	0	0	
CookieRfc6265UtilTest.java	D:\Master_Thesis\Github_Projects\act\rxf-couch\src\test\java\rxf\couch\CookieRf	D:\Master_Thesis\Github_Projects\act\rxf-core\src\main\java\rxf\c			3	1	0	0	0	0	0	0	0	0	
DateHeaderParserTest.java	D:\Master_Thesis\Github_Projects\act\rxf-couch\src\test\java\rxf\couch\DateHead	D:\Master_Thesis\Github_Projects\act\rxf-core\src\main\java\rxf\c			2	0	2	0	0	0	0	0	0	0	
Rfc822HeaderStateTest.java	D:\Master_Thesis\Github_Projects\act\rxf-couch\src\test\java\rxf\couch\Rfc822He	D:\Master_Thesis\Github_Projects\act\rxf-core\src\main\java\rxf\c			7	5	0	0	0	0	0	0	0	0	
CouchServiceTest.java	D:\Master_Thesis\Github_Projects\act\rxf-couch\src\test\java\rxf\couch\gen\Couc	D:\Master_Thesis\Github_Projects\act\rxf-couch\src\main\java\rxf			21	13	11	0	0	0	17	0	0	0	
CouchDriverTest.java	D:\Master_Thesis\Github_Projects\act\rxf-couch\src\test\java\rxf\couch\gen\Couc	D:\Master_Thesis\Github_Projects\act\rxf-couch\src\main\java\rxf			8	2	0	0	0	0	1	5	0	0	
CouchServiceProviderTest.java	D:\Master_Thesis\Github_Projects\act\rxf-guice\src\test\java\rxf\couch\guice\Cou	D:\Master_Thesis\Github_Projects\act\rxf-guice\src\main\java\rxf\			5	1	0	0	0	0	0	1	0	0	
RFServiceLayerModuleTest.jav	D:\Master_Thesis\Github_Projects\act\rxf-guice\src\test\java\rxf\couch\guice\RFS	D:\Master_Thesis\Github_Projects\act\rxf-guice\src\main\java\rxf\			0	0	0	0	0	0	0	0	0	0	
FileLogTest.java	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			4	2	2	0	0	0	2	0	0	0	
AddWorkspaceItemsTaskTest.j	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			8	3	0	0	0	0	3	0	0	0	
CacheDataUpdatedTaskTest.ja	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			6	1	1	0	0	0	3	0	0	0	
DbDowngradeHelperTest.java	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			6	2	0	0	0	0	4	4	2	0	
GridSizeMigrationTaskTest.java	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			17	0	2	1	0	0	11	0	0	0	
LoaderCursorTest.java	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			11	7	0	0	0	0	0	8	0	0	
PackageInstallStateChangedTa	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			6	0	0	0	0	0	3	0	0	0	
PopupPopulatorTest.java	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			7	0	0	0	0	0	0	0	0	0	
RestoreDbTaskTest.java	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			3	1	1	0	0	0	2	0	2	0	
SwipeDetectorTest.java	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			7	0	0	0	0	0	5	4	0	0	
FocusLogicTest.java	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			10	4	0	0	0	1	0	0	0	0	
GridOccupancyTest.java	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			3	2	0	0	0	0	0	0	0	0	
PreconditionsTest.java	D:\Master_Thesis\Github_Projects\mu-server\src\test\java\io\muserver\rest\Preco	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			8	6	0	0	0	0	6	0	0	0	
CMakeDocumentProviderTest.j	D:\Master_Thesis\Github_Projects\cmakeed\com.cthing.cmakeed.ui.tests\src\con	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			0	0	0	0	0	0	0	0	0	0	
WidgetsListAdapterTest.java	D:\Master_Thesis\Github_Projects\ALauncher\app\src\tests\java\com\android\lau	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			8	0	0	0	0	2	6	6	0	0	
AppTest.java	D:\Master_Thesis\Github_Projects\foss-parent\src\it\check-site-jacoco\src\test\jav	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			1	0	0	0	0	0	0	0	0	0	
SecurityHelperTest.java	D:\Master_Thesis\Github_Projects\cosmo\cosmo-core\src\test\unit\java\org\unite	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			11	5	0	0	0	0	5	7	0	0	
LocaleUtilsTest.java	D:\Master_Thesis\Github_Projects\BBQTimer\app\src\test\java\com\onefishtwo\b	D:\Master_Thesis\Github_Projects\ALauncher\app\src\main\java\			5	3	3	0	0	0	0	3	0	0	

Figure 5: Elements of columns_to_read list

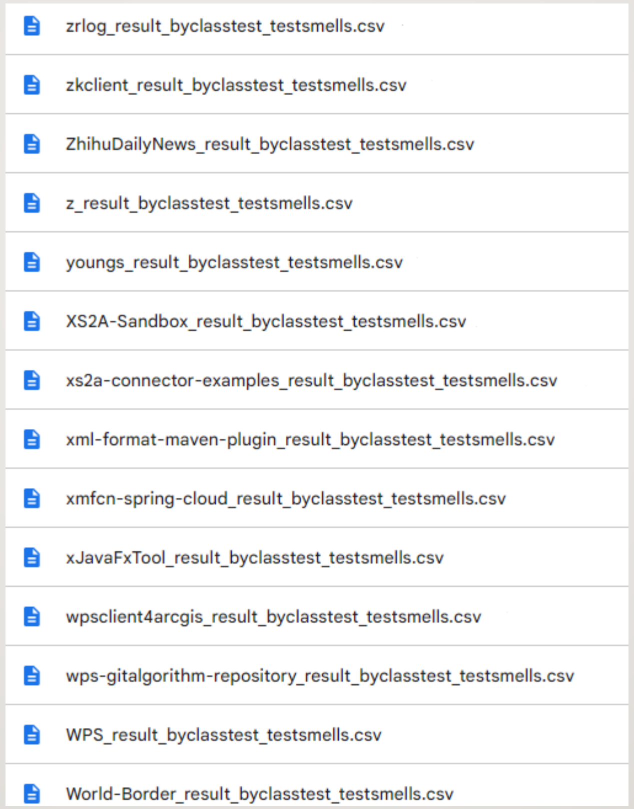


```
ApiTest.java:
  TestSmellDetectorTool: Assertion Roulette: 21
  TestSmellDetectorTool: Conditional Test Logic: 0
  TestSmellDetectorTool: Constructor_Initialization: 0
  TestSmellDetectorTool: Default Test: 0
  TestSmellDetectorTool: EmptyTest: 0
  TestSmellDetectorTool: Exception Catching Throwing: 20
  TestSmellDetectorTool: General Fixture: 1
  TestSmellDetectorTool: Mystery Guest: 0
  TestSmellDetectorTool: Print Statement: 0
  TestSmellDetectorTool: Redundant Assertion: 0
  TestSmellDetectorTool: Sensitive Equality: 1
  TestSmellDetectorTool: Verbose Test: 0
  TestSmellDetectorTool: Sleepy Test: 0
  TestSmellDetectorTool: Eager Test: 0
  TestSmellDetectorTool: Lazy Test: 0
  TestSmellDetectorTool: Duplicate Assert: 0
  TestSmellDetectorTool: Unknown Test: 0
  TestSmellDetectorTool: IgnoredTest: 0
  TestSmellDetectorTool: Resource Optimism: 0
  TestSmellDetectorTool: Magic Number Test: 21
  TestSmellDetectorTool: Dependent Test: 0
MainActivityTest.java:
  TestSmellDetectorTool: Assertion Roulette: 1
  TestSmellDetectorTool: Conditional Test Logic: 1
  TestSmellDetectorTool: Constructor_Initialization: 0
  TestSmellDetectorTool: Default Test: 0
  TestSmellDetectorTool: EmptyTest: 0
  TestSmellDetectorTool: Exception Catching Throwing: 2
  TestSmellDetectorTool: General Fixture: 0
  TestSmellDetectorTool: Mystery Guest: 0
  TestSmellDetectorTool: Print Statement: 0
  TestSmellDetectorTool: Redundant Assertion: 0
  TestSmellDetectorTool: Sensitive Equality: 0
  TestSmellDetectorTool: Verbose Test: 0
  TestSmellDetectorTool: Sleepy Test: 0
  TestSmellDetectorTool: Eager Test: 0
  TestSmellDetectorTool: Lazy Test: 0
  TestSmellDetectorTool: Duplicate Assert: 0
```

Figure 6: Part of contents of Output_of_TestSmellDetector_Tool.txt

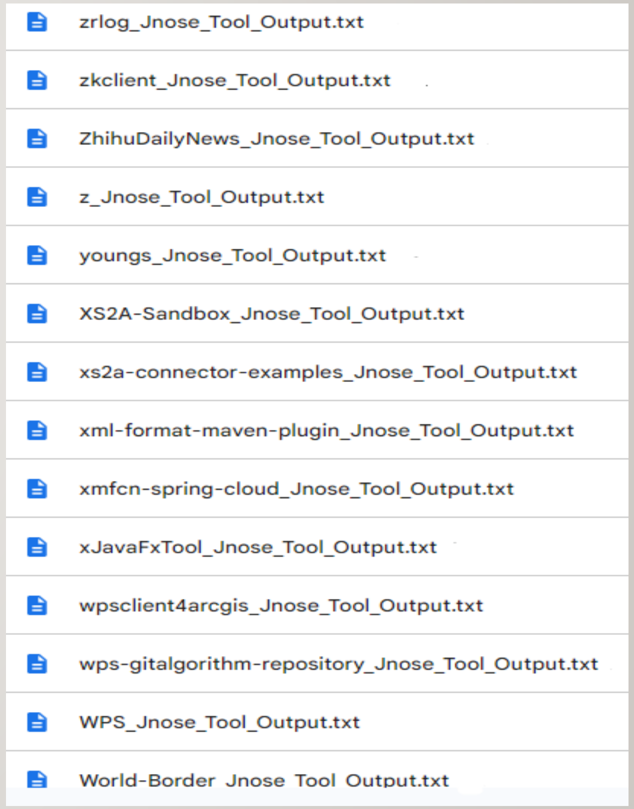
CASE STUDY - IMPLEMENTATION OF AUTOMATED SCRIPTS:

- read_csv_for_Jnose_tool: To parse CSV files output by JNose Tool (filenames follows a pattern "{project_name}_result_byclasstest_testsmells.csv") as shown in Figure 7. Also, it saves a results after parsing as "{project_name}_Output.txt" as shown in Figure 8 within a designated output folder.



zrlog_result_byclasstest_testsmells.csv
zkclient_result_byclasstest_testsmells.csv
ZhihuDailyNews_result_byclasstest_testsmells.csv
z_result_byclasstest_testsmells.csv
youngs_result_byclasstest_testsmells.csv
XS2A-Sandbox_result_byclasstest_testsmells.csv
xs2a-connector-examples_result_byclasstest_testsmells.csv
xml-format-maven-plugin_result_byclasstest_testsmells.csv
xmfcn-spring-cloud_result_byclasstest_testsmells.csv
xJavaFxTool_result_byclasstest_testsmells.csv
wpsclient4arcgis_result_byclasstest_testsmells.csv
wps-gitalgorithm-repository_result_byclasstest_testsmells.csv
WPS_result_byclasstest_testsmells.csv
World-Border_result_byclasstest_testsmells.csv

Figure 7: Output of JNose Tool after analysis



zrlog_Jnose_Tool_Output.txt
zkclient_Jnose_Tool_Output.txt
ZhihuDailyNews_Jnose_Tool_Output.txt
z_Jnose_Tool_Output.txt
youngs_Jnose_Tool_Output.txt
XS2A-Sandbox_Jnose_Tool_Output.txt
xs2a-connector-examples_Jnose_Tool_Output.txt
xml-format-maven-plugin_Jnose_Tool_Output.txt
xmfcn-spring-cloud_Jnose_Tool_Output.txt
xJavaFxTool_Jnose_Tool_Output.txt
wpsclient4arcgis_Jnose_Tool_Output.txt
wps-gitalgorithm-repository_Jnose_Tool_Output.txt
WPS_Jnose_Tool_Output.txt
World-Border_Jnose_Tool_Output.txt

Figure 8: Output of read_csv_for_Jnose_tool function

CASE STUDY - IMPLEMENTATİON OF AUTOMATED SCRIPTS:

- merge_txt_files(file_paths, output_file) function and updated_merge_txt_files(input_file_path, output_file_path) function: To merge results by two different tools, into one conclusive file titled "Merged_output_txt_file.txt". After merging, findings might not be next to each other. Therefore, to reorganize findings, updated_merge_txt_files is called.

CASE STUDY - IMPLEMENTATİON OF AUTOMATED SCRIPTS:

- comparing_results_of_each_tool.py
  - To compare the results of different testing methods which are used in the detection of smells. Co-occurrence Analysis, Ratio Calculation and Comparison and Visualization are done in this file.
- jnose_website.py
  - To accesses the webpage which is related to Jnose Tool. It automatically inputs GitHub project links into the local server address "http://127.0.0.1:8080" and analyze each project. Then, it downloads results in the .CSV format.

CASE STUDY - RESULTS

- The JNose Tool detected 81773 test smells in total using all files. The TestSmellDetector tool detected 89497 test smells in total using all files.
- 5478 files were used for this analysis.

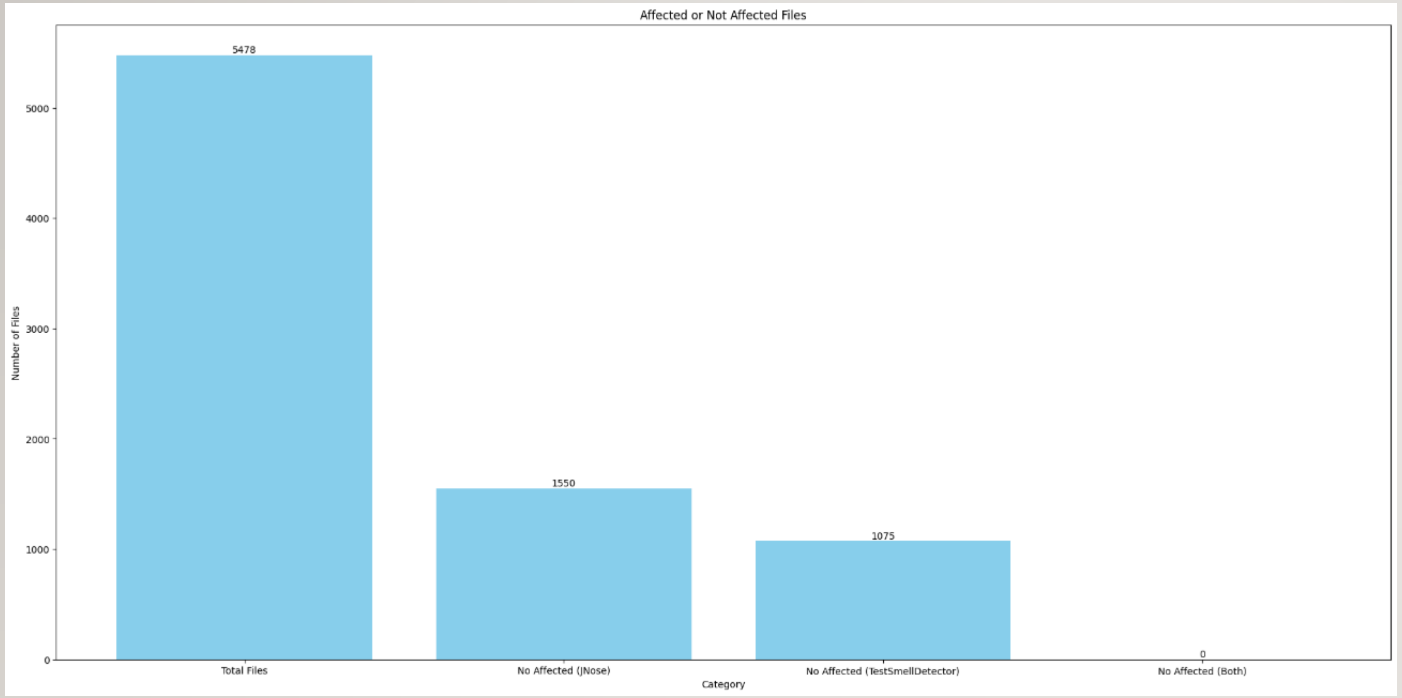


Figure 9: Number of Affected and not Affected Files

- Figure 9 shows that the Jnose Tool identified 1550 files that exhibited no test smells, In contrast, the TestSmellDetector Tool demonstrated a higher identification rate, with 1075 files reported as unaffected.

CASE STUDY - TOTAL NUMBER OF TEST SMELLS

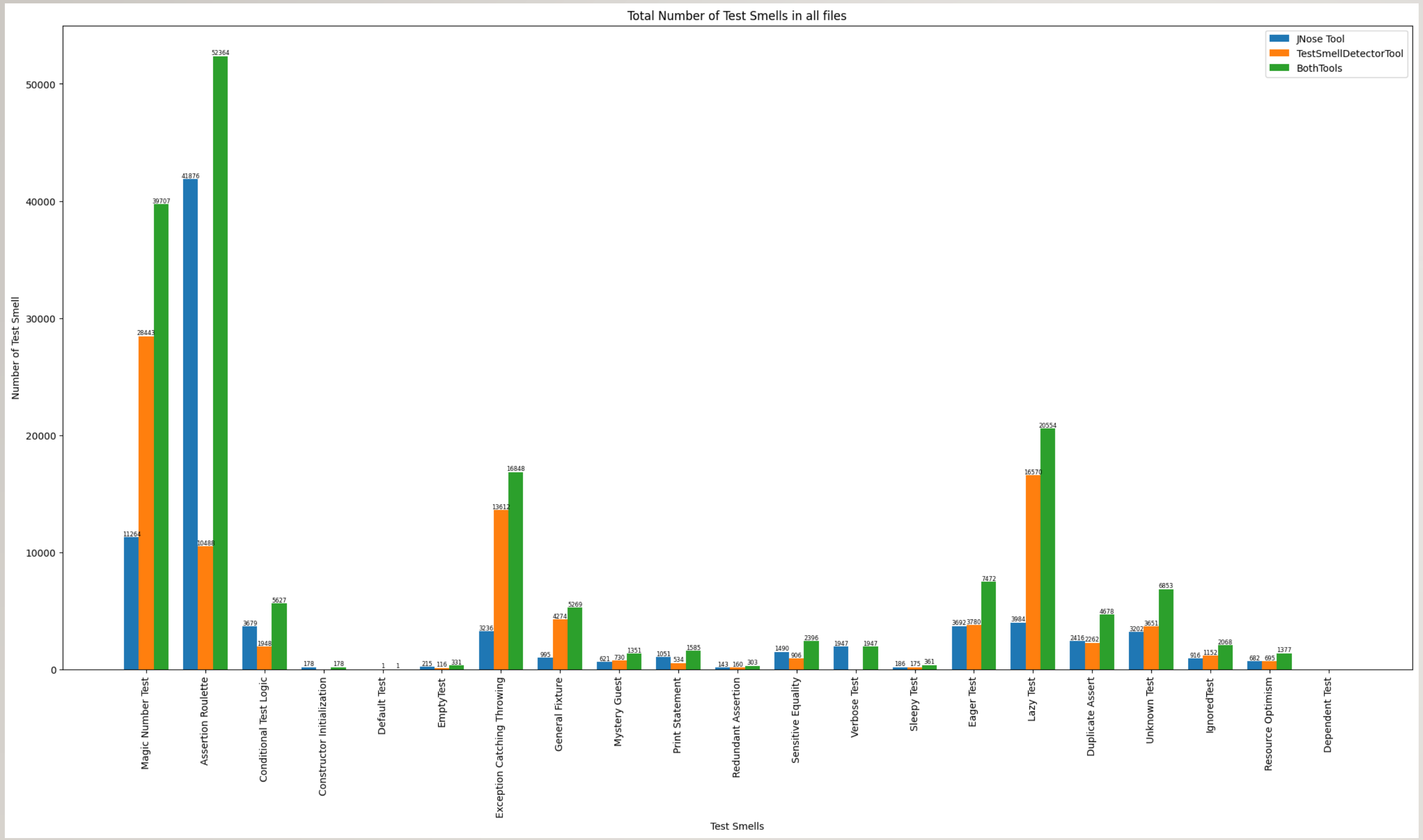


Figure 10: Total Number of Test Smells with using JNose and TestSmellDetector Tools in all files

- TestSmellDetector is very effective in detecting 'Magic Number Test' smell with 28,443 detection rates
- TestSmellDetector Tool also detected with high rate to other types of test smells like 'Exception Catching Throwing' and 'Lazy Test' which the tool detected 13,612 and 16,570 occurrences.
- For 'Assertion Roulette, TestSmellDetector Tool detected 10,488 occurence.

CASE STUDY - TOTAL NUMBER OF TEST SMELLS

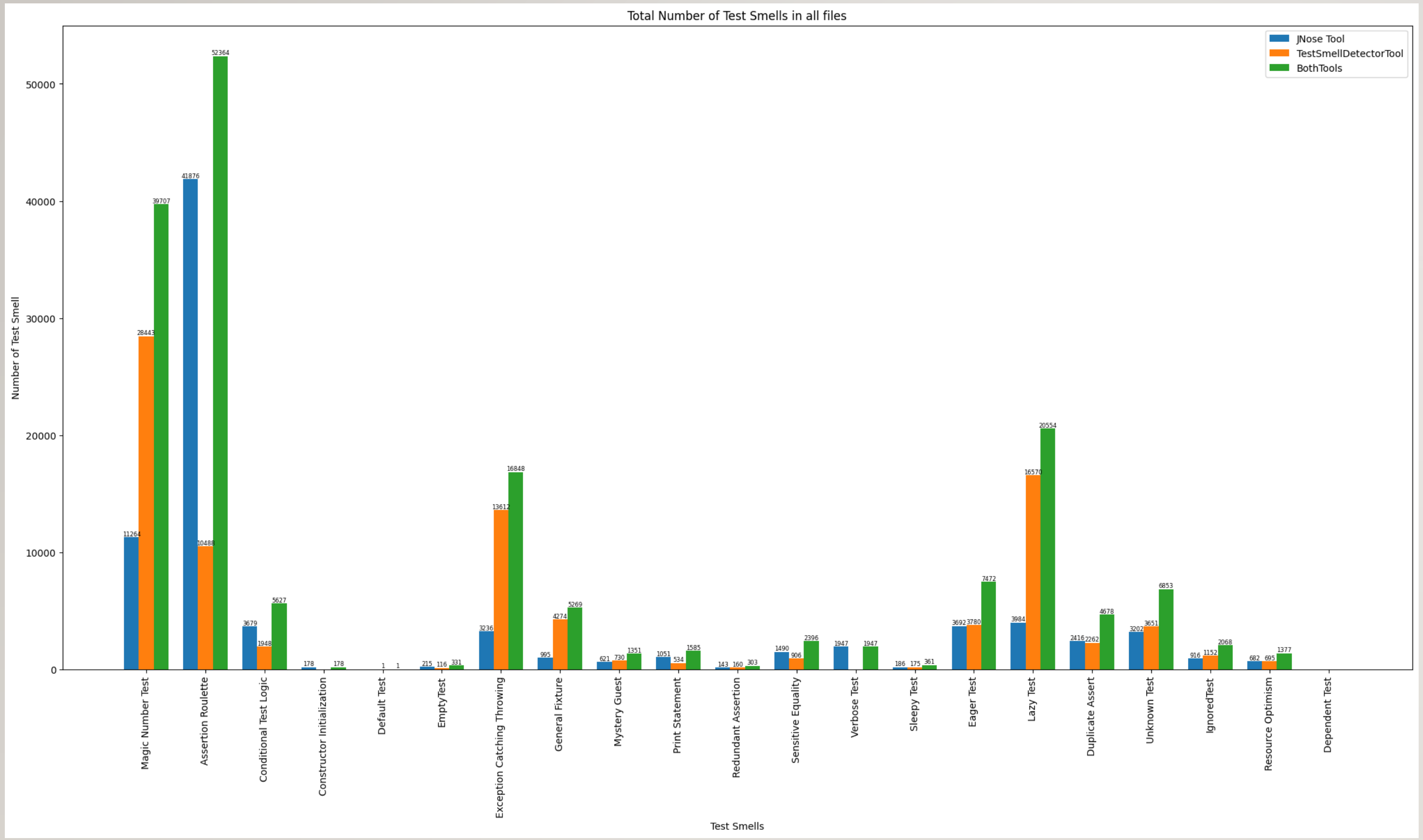


Figure 11: Total Number of Test Smells with using JNose and TestSmellDetector Tools in all files

- JNose Tool is more effective for detecting the 'Assertion Roulette with 41,876 occurence.
- The JNose Tool exhibits greater detection rates for the 'Magic Number Test' and 'Lazy Test', with detection rates of 11,264 and 3984 occurrences, respectively.
- JNose tool performed high detection rates: 'Eager Test' with detection rate of 3692

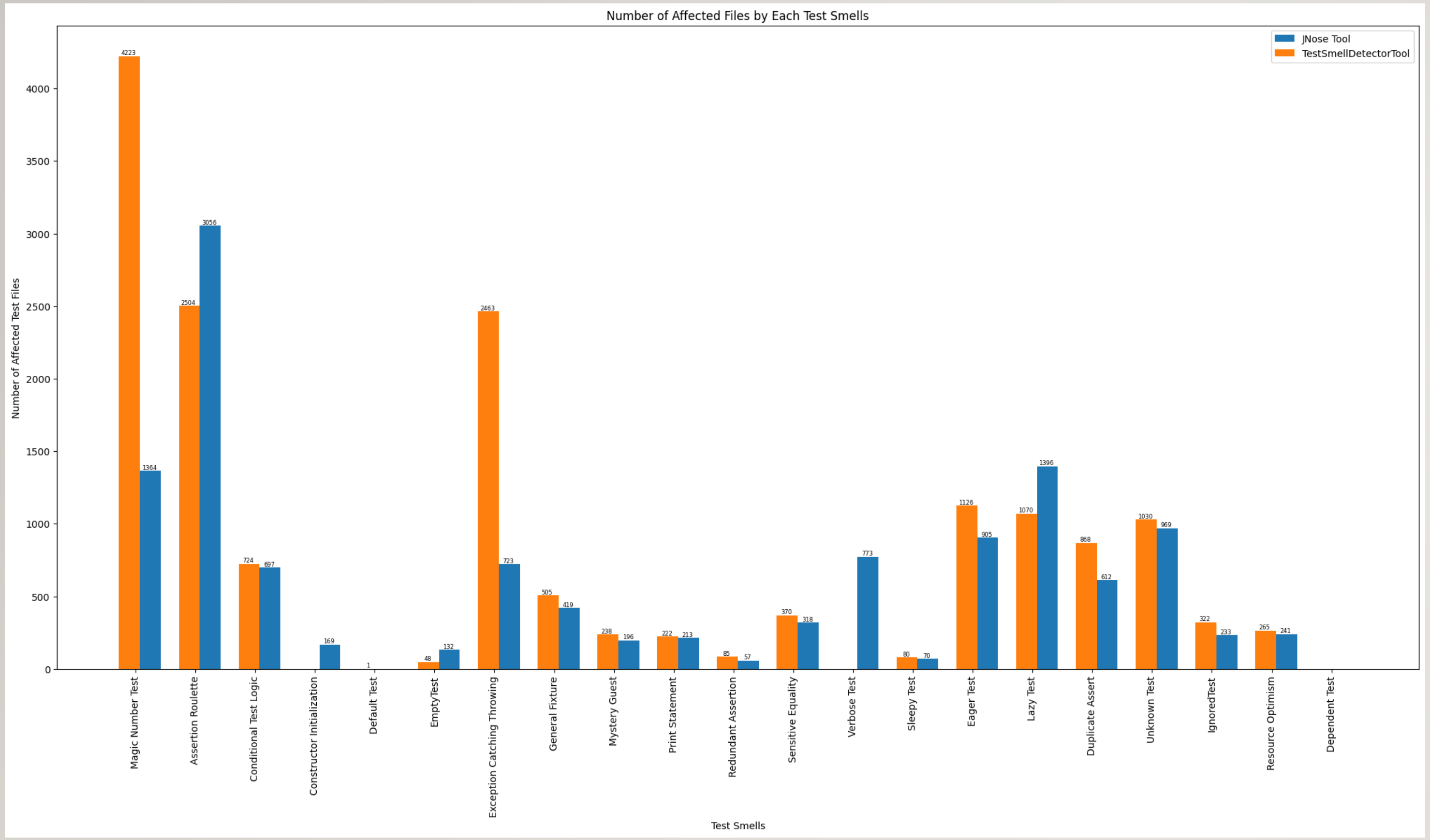
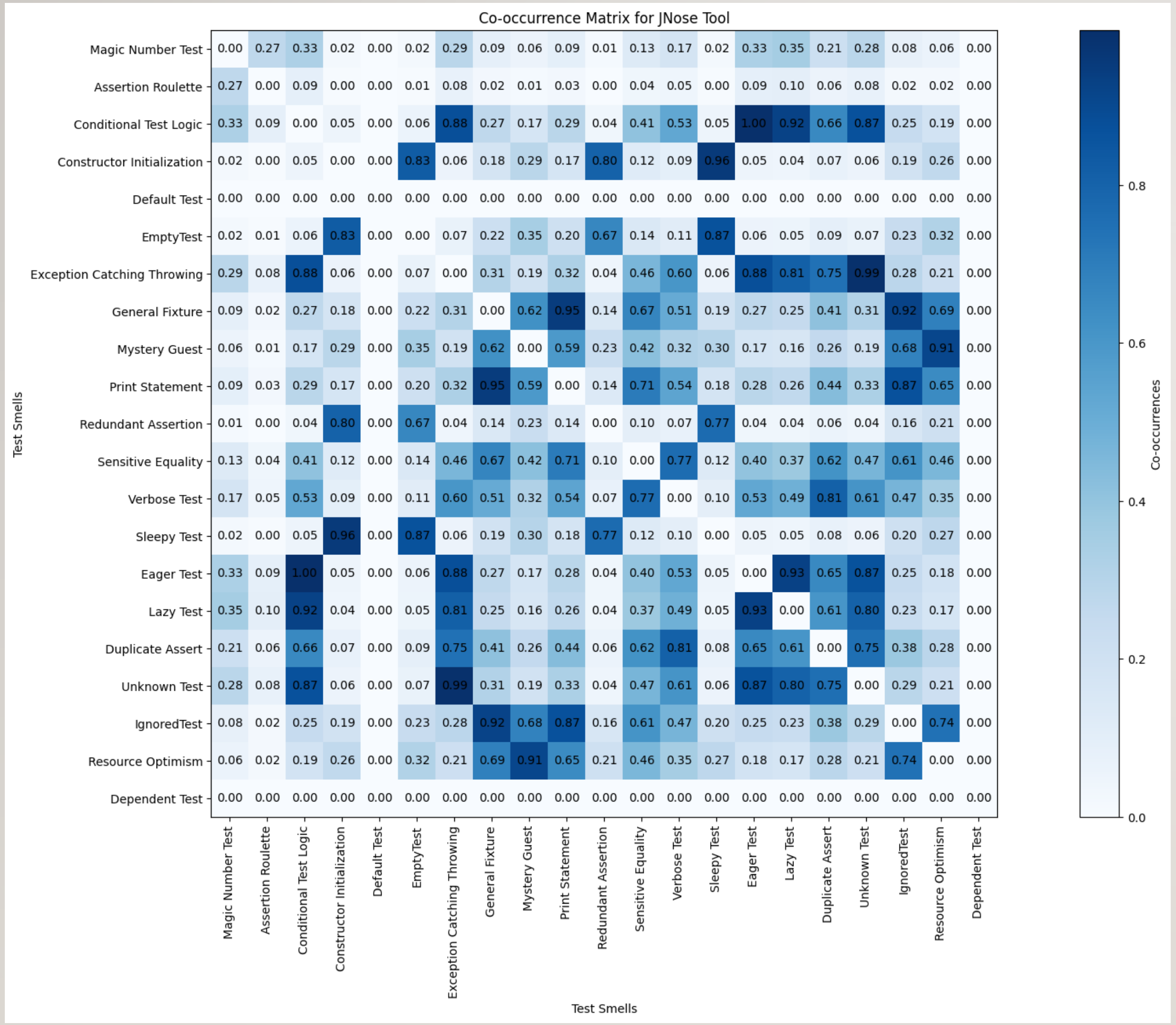


Figure 12: Number of Affected Files by Each Test Smells

CASE STUDY - NUMBER OF AFFECTED FILES BY EACH TEST SMELLS

- By using the TestSmellDetector tool, highest numbers of affected files by 'Magic Number Test', 'Assertion Roulette', 'Exception Catching Throwing', 'Eager Test', 'Lazy Test', and 'Unknown Test' are detected as 4222, 2503, 2463, 1126, 1070, and 1030.

- By using the JNose tool, highest numbers of affected files by 'Assertion Roulette', 'Lazy Test', 'Magic Number Test', 'Exception Catching Throwing', 'Unknown Test', and 'Eager Test' are detected as 3056, 1396, 1364, 969, and 905.

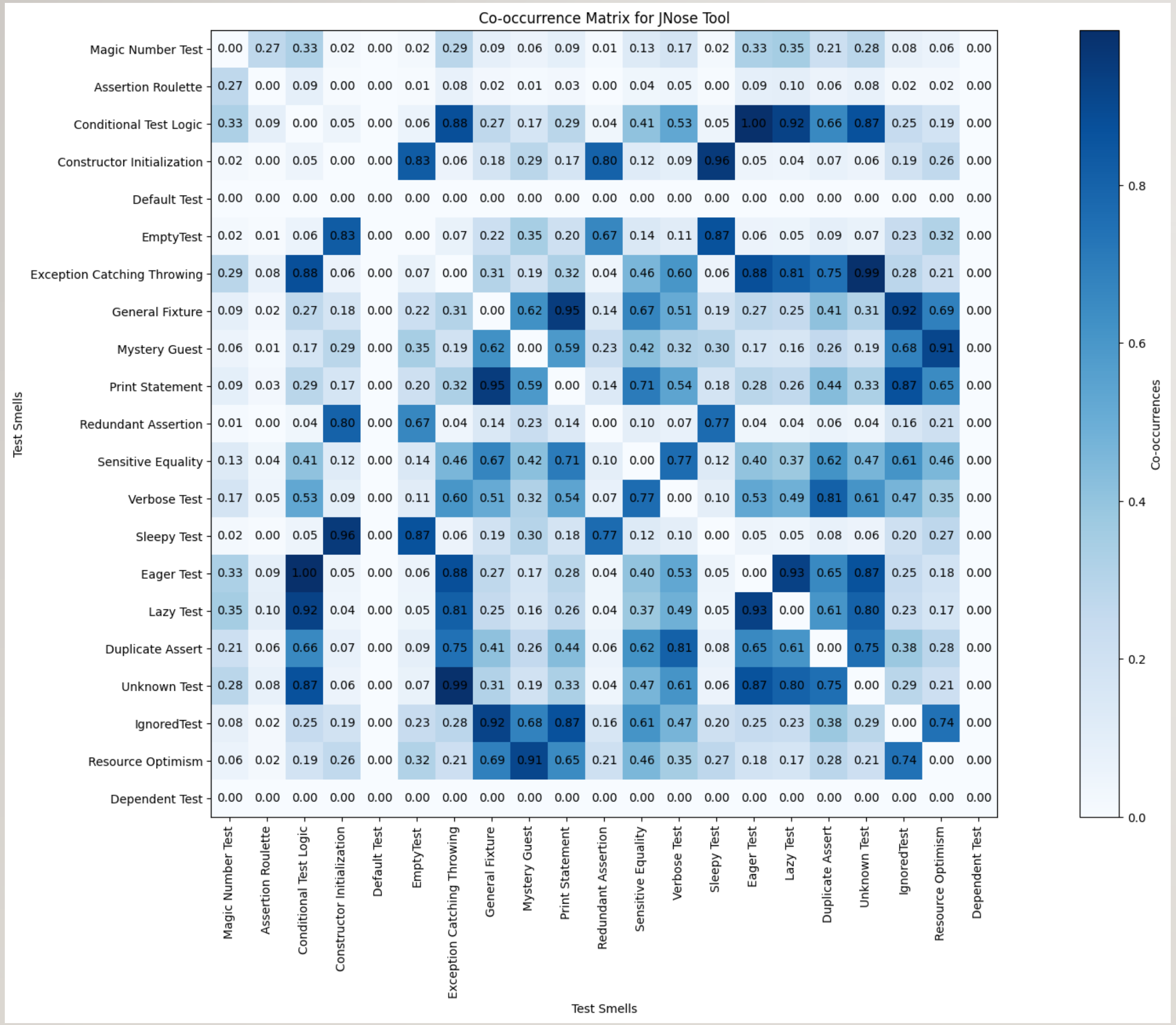


	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.27	0.33	0.02	0.00	0.02	0.29	0.09	0.06	0.09	0.01	0.13	0.17	0.02	0.33	0.35	0.21	0.28	0.08	0.06	0.00
Assertion Roulette	0.27	0.00	0.09	0.00	0.00	0.01	0.08	0.02	0.01	0.03	0.00	0.04	0.05	0.00	0.09	0.10	0.06	0.08	0.02	0.02	0.00
Conditional Test Logic	0.33	0.09	0.00	0.05	0.00	0.06	0.88	0.27	0.17	0.29	0.04	0.41	0.53	0.05	1.00	0.92	0.66	0.87	0.25	0.19	0.00
Constructor Initialization	0.02	0.00	0.05	0.00	0.00	0.83	0.06	0.18	0.29	0.17	0.80	0.12	0.09	0.96	0.05	0.04	0.07	0.06	0.19	0.26	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.02	0.01	0.06	0.83	0.00	0.00	0.07	0.22	0.35	0.20	0.67	0.14	0.11	0.87	0.06	0.05	0.09	0.07	0.23	0.32	0.00
Exception Catching Throwing	0.29	0.08	0.88	0.06	0.00	0.07	0.00	0.31	0.19	0.32	0.04	0.46	0.60	0.06	0.88	0.81	0.75	0.99	0.28	0.21	0.00
General Fixture	0.09	0.02	0.27	0.18	0.00	0.22	0.31	0.00	0.62	0.95	0.14	0.67	0.51	0.19	0.27	0.25	0.41	0.31	0.92	0.69	0.00
Mystery Guest	0.06	0.01	0.17	0.29	0.00	0.35	0.19	0.62	0.00	0.59	0.23	0.42	0.32	0.30	0.17	0.16	0.26	0.19	0.68	0.91	0.00
Print Statement	0.09	0.03	0.29	0.17	0.00	0.20	0.32	0.95	0.59	0.00	0.14	0.71	0.54	0.18	0.28	0.26	0.44	0.33	0.87	0.65	0.00
Redundant Assertion	0.01	0.00	0.04	0.80	0.00	0.67	0.04	0.14	0.23	0.14	0.00	0.10	0.07	0.77	0.04	0.04	0.06	0.04	0.16	0.21	0.00
Sensitive Equality	0.13	0.04	0.41	0.12	0.00	0.14	0.46	0.67	0.42	0.71	0.10	0.00	0.77	0.12	0.40	0.37	0.62	0.47	0.61	0.46	0.00
Verbose Test	0.17	0.05	0.53	0.09	0.00	0.11	0.60	0.51	0.32	0.54	0.07	0.77	0.00	0.10	0.53	0.49	0.81	0.61	0.47	0.35	0.00
Sleepy Test	0.02	0.00	0.05	0.96	0.00	0.87	0.06	0.19	0.30	0.18	0.77	0.12	0.10	0.00	0.05	0.05	0.08	0.06	0.20	0.27	0.00
Eager Test	0.33	0.09	1.00	0.05	0.00	0.06	0.88	0.27	0.17	0.28	0.04	0.40	0.53	0.05	0.00	0.93	0.65	0.87	0.25	0.18	0.00
Lazy Test	0.35	0.10	0.92	0.04	0.00	0.05	0.81	0.25	0.16	0.26	0.04	0.37	0.49	0.05	0.93	0.00	0.61	0.80	0.23	0.17	0.00
Duplicate Assert	0.21	0.06	0.66	0.07	0.00	0.09	0.75	0.41	0.26	0.44	0.06	0.62	0.81	0.08	0.65	0.61	0.00	0.75	0.38	0.28	0.00
Unknown Test	0.28	0.08	0.87	0.06	0.00	0.07	0.99	0.31	0.19	0.33	0.04	0.47	0.61	0.06	0.87	0.80	0.75	0.00	0.29	0.21	0.00
IgnoredTest	0.08	0.02	0.25	0.19	0.00	0.23	0.28	0.92	0.68	0.87	0.16	0.61	0.47	0.20	0.25	0.23	0.38	0.29	0.00	0.74	0.00
Resource Optimism	0.06	0.02	0.19	0.26	0.00	0.32	0.21	0.69	0.91	0.65	0.21	0.46	0.35	0.27	0.18	0.17	0.28	0.21	0.74	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 13: Co-occurrence Matrix for JNose Tool

CASE STUDY - CO-OCCURRENCE OF TEST SMELLS BASED ON JNOSE TOOL

- Between 'Conditional Test Logic' and 'Eager Test' co-occurrence value is [1.00].
- Co-occurrence rate of the pairing of 'Exception Catching Throwing' with 'Unknown Test' is [0.99].
- Next strong correlations are the one observed between 'Sleepy Test' and 'Constructor Initialization', with a co-occurrence value of [0.96].



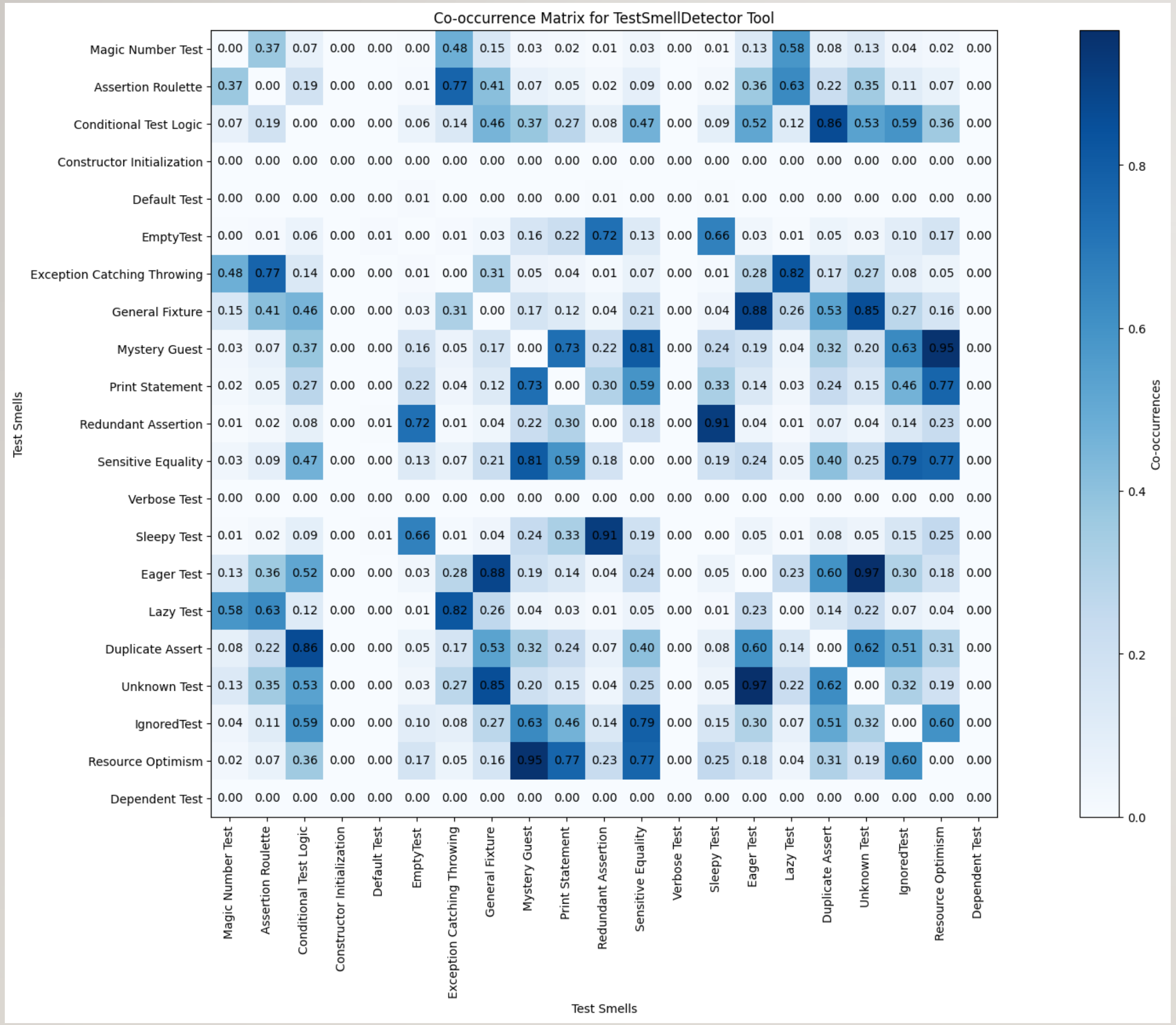
	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.27	0.33	0.02	0.00	0.02	0.29	0.09	0.06	0.09	0.01	0.13	0.17	0.02	0.33	0.35	0.21	0.28	0.08	0.06	0.00
Assertion Roulette	0.27	0.00	0.09	0.00	0.00	0.01	0.08	0.02	0.01	0.03	0.00	0.04	0.05	0.00	0.09	0.10	0.06	0.08	0.02	0.02	0.00
Conditional Test Logic	0.33	0.09	0.00	0.05	0.00	0.06	0.88	0.27	0.17	0.29	0.04	0.41	0.53	0.05	1.00	0.92	0.66	0.87	0.25	0.19	0.00
Constructor Initialization	0.02	0.00	0.05	0.00	0.00	0.83	0.06	0.18	0.29	0.17	0.80	0.12	0.09	0.96	0.05	0.04	0.07	0.06	0.19	0.26	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.02	0.01	0.06	0.83	0.00	0.00	0.07	0.22	0.35	0.20	0.67	0.14	0.11	0.87	0.06	0.05	0.09	0.07	0.23	0.32	0.00
Exception Catching Throwing	0.29	0.08	0.88	0.06	0.00	0.07	0.00	0.31	0.19	0.32	0.04	0.46	0.60	0.06	0.88	0.81	0.75	0.99	0.28	0.21	0.00
General Fixture	0.09	0.02	0.27	0.18	0.00	0.22	0.31	0.00	0.62	0.95	0.14	0.67	0.51	0.19	0.27	0.25	0.41	0.31	0.92	0.69	0.00
Mystery Guest	0.06	0.01	0.17	0.29	0.00	0.35	0.19	0.62	0.00	0.59	0.23	0.42	0.32	0.30	0.17	0.16	0.26	0.19	0.68	0.91	0.00
Print Statement	0.09	0.03	0.29	0.17	0.00	0.20	0.32	0.95	0.59	0.00	0.14	0.71	0.54	0.18	0.28	0.26	0.44	0.33	0.87	0.65	0.00
Redundant Assertion	0.01	0.00	0.04	0.80	0.00	0.67	0.04	0.14	0.23	0.14	0.00	0.10	0.07	0.77	0.04	0.04	0.06	0.04	0.16	0.21	0.00
Sensitive Equality	0.13	0.04	0.41	0.12	0.00	0.14	0.46	0.67	0.42	0.71	0.10	0.00	0.77	0.12	0.40	0.37	0.62	0.47	0.61	0.46	0.00
Verbose Test	0.17	0.05	0.53	0.09	0.00	0.11	0.60	0.51	0.32	0.54	0.07	0.77	0.00	0.10	0.53	0.49	0.81	0.61	0.47	0.35	0.00
Sleepy Test	0.02	0.00	0.05	0.96	0.00	0.87	0.06	0.19	0.30	0.18	0.77	0.12	0.10	0.00	0.05	0.05	0.08	0.06	0.20	0.27	0.00
Eager Test	0.33	0.09	1.00	0.05	0.00	0.06	0.88	0.27	0.17	0.28	0.04	0.40	0.53	0.05	0.00	0.93	0.65	0.87	0.25	0.18	0.00
Lazy Test	0.35	0.10	0.92	0.04	0.00	0.05	0.81	0.25	0.16	0.26	0.04	0.37	0.49	0.05	0.93	0.00	0.61	0.80	0.23	0.17	0.00
Duplicate Assert	0.21	0.06	0.66	0.07	0.00	0.09	0.75	0.41	0.26	0.44	0.06	0.62	0.81	0.08	0.65	0.61	0.00	0.75	0.38	0.28	0.00
Unknown Test	0.28	0.08	0.87	0.06	0.00	0.07	0.99	0.31	0.19	0.33	0.04	0.47	0.61	0.06	0.87	0.80	0.75	0.00	0.29	0.21	0.00
IgnoredTest	0.08	0.02	0.25	0.19	0.00	0.23	0.28	0.92	0.68	0.87	0.16	0.61	0.47	0.20	0.25	0.23	0.38	0.29	0.00	0.74	0.00
Resource Optimism	0.06	0.02	0.19	0.26	0.00	0.32	0.21	0.69	0.91	0.65	0.21	0.46	0.35	0.27	0.18	0.17	0.28	0.21	0.74	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 14: Co-occurrence Matrix for JNose Tool

CASE STUDY - CO-OCCURRENCE OF TEST SMELLS BASED ON JNOSE TOOL

- 'Magic Number Test' and 'Redundant Assertion', with a negligible co-occurrence rate of [0.01].
- 'Mystery Guest' and 'Assertion Roulette' and, 'Empty Test' and 'Assertion Roulette' where the co-occurrence rate stands at [0.01] for both pairs.

CASE STUDY - CO-OCCURRENCE OF TEST SMELLS BASED ON TESTSMELLDETECTOR TOOL

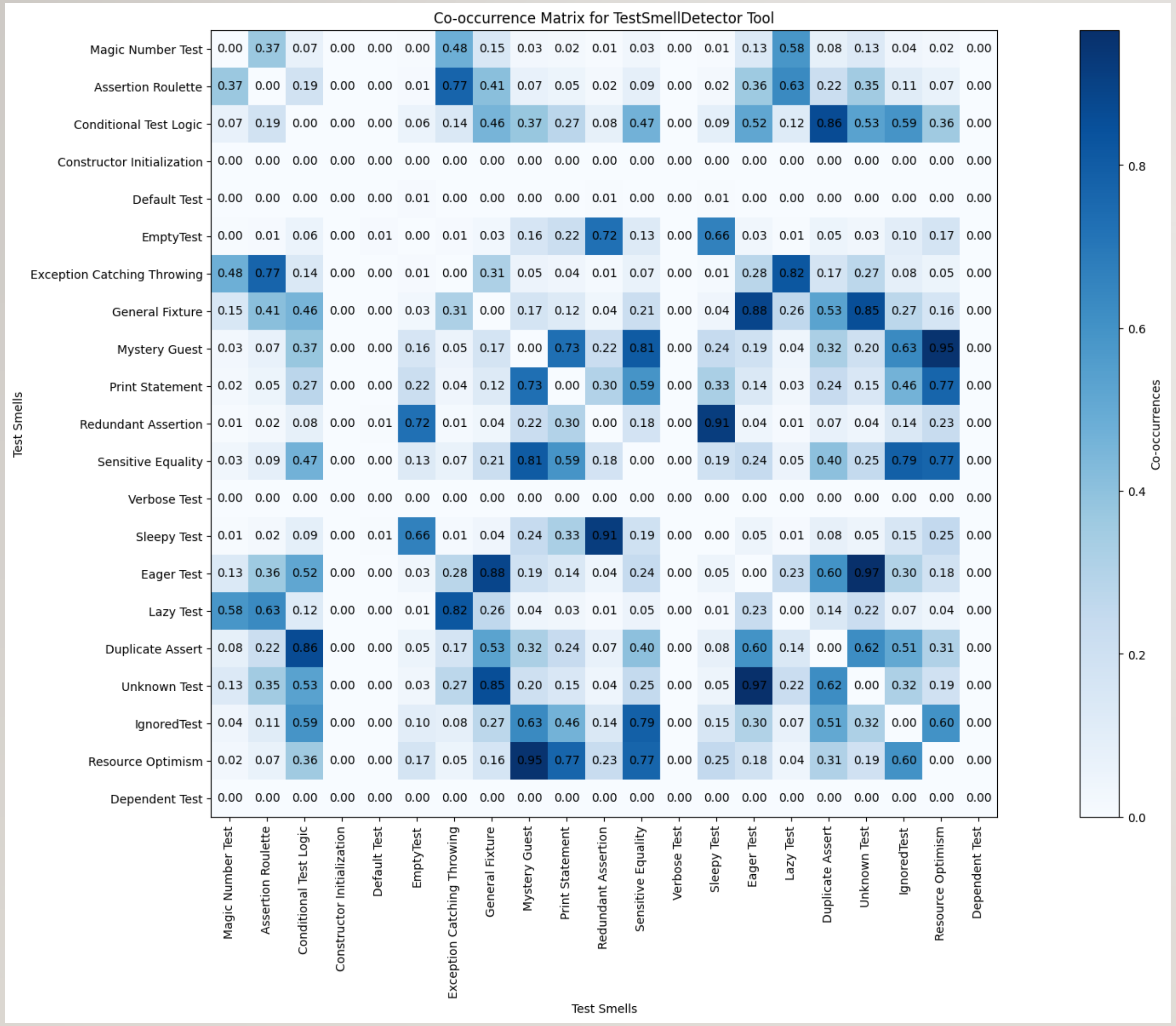


	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.37	0.07	0.00	0.00	0.00	0.48	0.15	0.03	0.02	0.01	0.03	0.00	0.01	0.13	0.58	0.08	0.13	0.04	0.02	0.00
Assertion Roulette	0.37	0.00	0.19	0.00	0.00	0.01	0.77	0.41	0.07	0.05	0.02	0.09	0.00	0.02	0.36	0.63	0.22	0.35	0.11	0.07	0.00
Conditional Test Logic	0.07	0.19	0.00	0.00	0.00	0.06	0.14	0.46	0.37	0.27	0.08	0.47	0.00	0.09	0.52	0.12	0.86	0.53	0.59	0.36	0.00
Constructor Initialization	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.00	0.01	0.06	0.00	0.01	0.00	0.01	0.03	0.16	0.22	0.72	0.13	0.00	0.66	0.03	0.01	0.05	0.03	0.10	0.17	0.00
Exception Catching Throwing	0.48	0.77	0.14	0.00	0.00	0.01	0.00	0.31	0.05	0.04	0.01	0.07	0.00	0.01	0.28	0.82	0.17	0.27	0.08	0.05	0.00
General Fixture	0.15	0.41	0.46	0.00	0.00	0.03	0.31	0.00	0.17	0.12	0.04	0.21	0.00	0.04	0.88	0.26	0.53	0.85	0.27	0.16	0.00
Mystery Guest	0.03	0.07	0.37	0.00	0.00	0.16	0.05	0.17	0.00	0.73	0.22	0.81	0.00	0.24	0.19	0.04	0.32	0.20	0.63	0.95	0.00
Print Statement	0.02	0.05	0.27	0.00	0.00	0.22	0.04	0.12	0.73	0.00	0.30	0.59	0.00	0.33	0.14	0.03	0.24	0.15	0.46	0.77	0.00
Redundant Assertion	0.01	0.02	0.08	0.00	0.01	0.72	0.01	0.04	0.22	0.30	0.00	0.18	0.00	0.91	0.04	0.01	0.07	0.04	0.14	0.23	0.00
Sensitive Equality	0.03	0.09	0.47	0.00	0.00	0.13	0.07	0.21	0.81	0.59	0.18	0.00	0.00	0.19	0.24	0.05	0.40	0.25	0.79	0.77	0.00
Verbose Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sleepy Test	0.01	0.02	0.09	0.00	0.01	0.66	0.01	0.04	0.24	0.33	0.91	0.19	0.00	0.00	0.05	0.01	0.08	0.05	0.15	0.25	0.00
Eager Test	0.13	0.36	0.52	0.00	0.00	0.03	0.28	0.88	0.19	0.14	0.04	0.24	0.00	0.05	0.00	0.23	0.60	0.97	0.30	0.18	0.00
Lazy Test	0.58	0.63	0.12	0.00	0.00	0.01	0.82	0.26	0.04	0.03	0.01	0.05	0.00	0.01	0.23	0.00	0.14	0.22	0.07	0.04	0.00
Duplicate Assert	0.08	0.22	0.86	0.00	0.00	0.05	0.17	0.53	0.32	0.24	0.07	0.40	0.00	0.08	0.60	0.14	0.00	0.62	0.51	0.31	0.00
Unknown Test	0.13	0.35	0.53	0.00	0.00	0.03	0.27	0.85	0.20	0.15	0.04	0.25	0.00	0.05	0.97	0.22	0.62	0.00	0.32	0.19	0.00
IgnoredTest	0.04	0.11	0.59	0.00	0.00	0.10	0.08	0.27	0.63	0.46	0.14	0.79	0.00	0.15	0.30	0.07	0.51	0.32	0.00	0.60	0.00
Resource Optimism	0.02	0.07	0.36	0.00	0.00	0.17	0.05	0.16	0.95	0.77	0.23	0.77	0.00	0.25	0.18	0.04	0.31	0.19	0.60	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 15: Co-occurrence Matrix for TestSmellDetector Tool

- Between 'Unknown Test' and 'Eager Test' and their co-occurrence value is [0.97].
- The pairing of 'Source Optimism' with 'Mystery Guest' has a strong co-occurrence rate of [0.95]

CASE STUDY - CO-OCCURRENCE OF TEST SMELLS BASED ON TESTSMELLDETECTOR TOOL



Test Smells	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.37	0.07	0.00	0.00	0.00	0.48	0.15	0.03	0.02	0.01	0.03	0.00	0.01	0.13	0.58	0.08	0.13	0.04	0.02	0.00
Assertion Roulette	0.37	0.00	0.19	0.00	0.00	0.01	0.77	0.41	0.07	0.05	0.02	0.09	0.00	0.02	0.36	0.63	0.22	0.35	0.11	0.07	0.00
Conditional Test Logic	0.07	0.19	0.00	0.00	0.00	0.06	0.14	0.46	0.37	0.27	0.08	0.47	0.00	0.09	0.52	0.12	0.86	0.53	0.59	0.36	0.00
Constructor Initialization	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.00	0.01	0.06	0.00	0.01	0.00	0.01	0.03	0.16	0.22	0.72	0.13	0.00	0.66	0.03	0.01	0.05	0.03	0.10	0.17	0.00
Exception Catching Throwing	0.48	0.77	0.14	0.00	0.00	0.01	0.00	0.31	0.05	0.04	0.01	0.07	0.00	0.01	0.28	0.82	0.17	0.27	0.08	0.05	0.00
General Fixture	0.15	0.41	0.46	0.00	0.00	0.03	0.31	0.00	0.17	0.12	0.04	0.21	0.00	0.04	0.88	0.26	0.53	0.85	0.27	0.16	0.00
Mystery Guest	0.03	0.07	0.37	0.00	0.00	0.16	0.05	0.17	0.00	0.73	0.22	0.81	0.00	0.24	0.19	0.04	0.32	0.20	0.63	0.95	0.00
Print Statement	0.02	0.05	0.27	0.00	0.00	0.22	0.04	0.12	0.73	0.00	0.30	0.59	0.00	0.33	0.14	0.03	0.24	0.15	0.46	0.77	0.00
Redundant Assertion	0.01	0.02	0.08	0.00	0.01	0.72	0.01	0.04	0.22	0.30	0.00	0.18	0.00	0.91	0.04	0.01	0.07	0.04	0.14	0.23	0.00
Sensitive Equality	0.03	0.09	0.47	0.00	0.00	0.13	0.07	0.21	0.81	0.59	0.18	0.00	0.00	0.19	0.24	0.05	0.40	0.25	0.79	0.77	0.00
Verbose Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sleepy Test	0.01	0.02	0.09	0.00	0.01	0.66	0.01	0.04	0.24	0.33	0.91	0.19	0.00	0.00	0.05	0.01	0.08	0.05	0.15	0.25	0.00
Eager Test	0.13	0.36	0.52	0.00	0.00	0.03	0.28	0.88	0.19	0.14	0.04	0.24	0.00	0.05	0.00	0.23	0.60	0.97	0.30	0.18	0.00
Lazy Test	0.58	0.63	0.12	0.00	0.00	0.01	0.82	0.26	0.04	0.03	0.01	0.05	0.00	0.01	0.23	0.00	0.14	0.22	0.07	0.04	0.00
Duplicate Assert	0.08	0.22	0.86	0.00	0.00	0.05	0.17	0.53	0.32	0.24	0.07	0.40	0.00	0.08	0.60	0.14	0.00	0.62	0.51	0.31	0.00
Unknown Test	0.13	0.35	0.53	0.00	0.00	0.03	0.27	0.85	0.20	0.15	0.04	0.25	0.00	0.05	0.97	0.22	0.62	0.00	0.32	0.19	0.00
IgnoredTest	0.04	0.11	0.59	0.00	0.00	0.10	0.08	0.27	0.63	0.46	0.14	0.79	0.00	0.15	0.30	0.07	0.51	0.32	0.00	0.60	0.00
Resource Optimism	0.02	0.07	0.36	0.00	0.00	0.17	0.05	0.16	0.95	0.77	0.23	0.77	0.00	0.25	0.18	0.04	0.31	0.19	0.60	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 16: Co-occurrence Matrix for TestSmellDetector Tool

- Between 'Magic Number Test' and 'Redundant Assertion', 'Magic Number Test' and 'Sleepy Test', 'Assertion Roulette' and 'Empty Test', 'Empty Test' and 'Exception Catching Throwing', 'Empty Test' and 'Lazy Test', so on with a negligible co-occurrence rate of [0.01]

DISCUSSION - TOTAL NUMBER OF TEST SMELLS

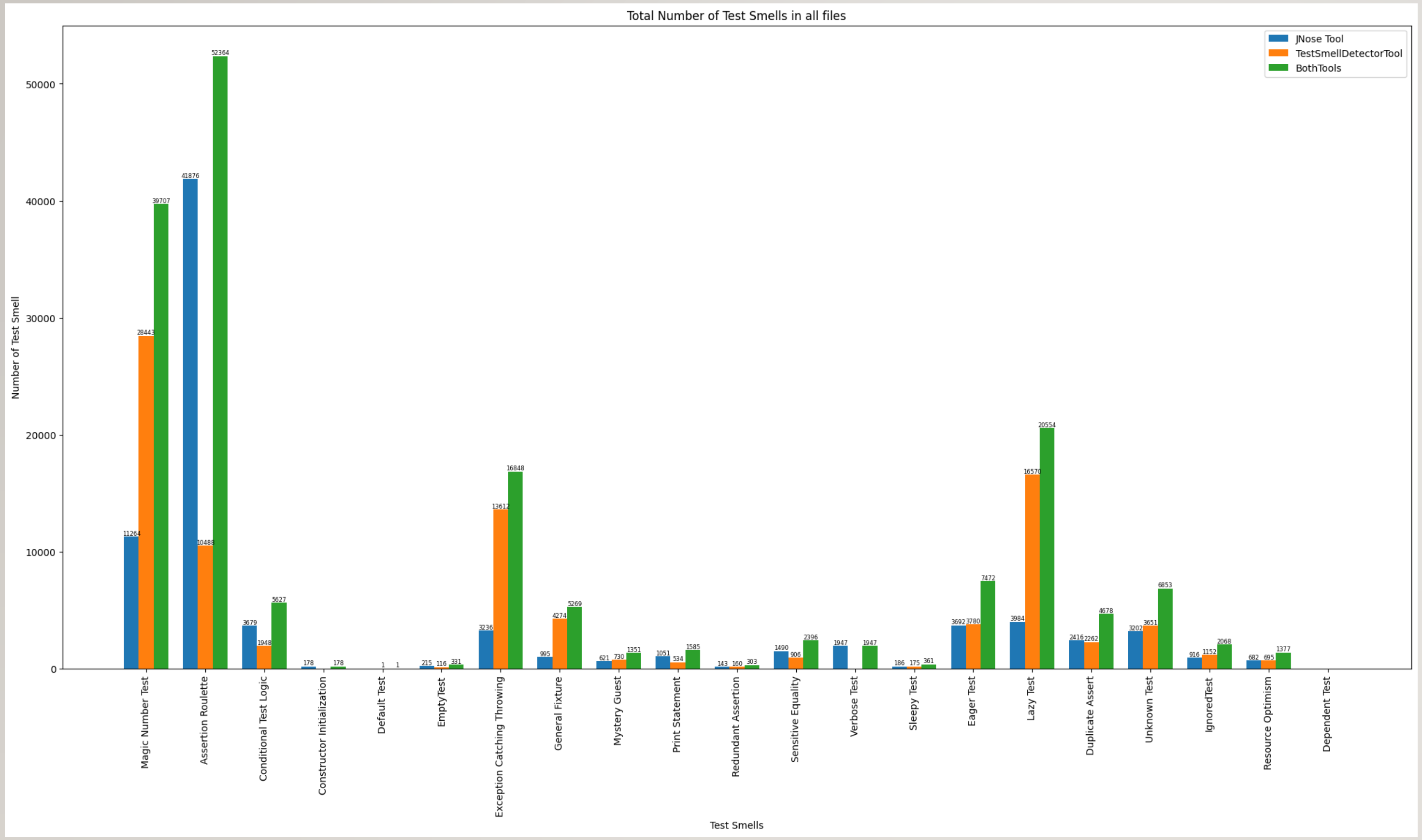


Figure 17: Total Number of Test Smells with using JNose and TestSmellDetector Tools in all files

- Used GitHub projects have the smells that we mentioned above mostly and have bad code quality.
- For 5 most detected test smells, the reason might be like as following:
  - For 'Assertion Roulette', there are added several assertions to a single test to check multiple conditions.

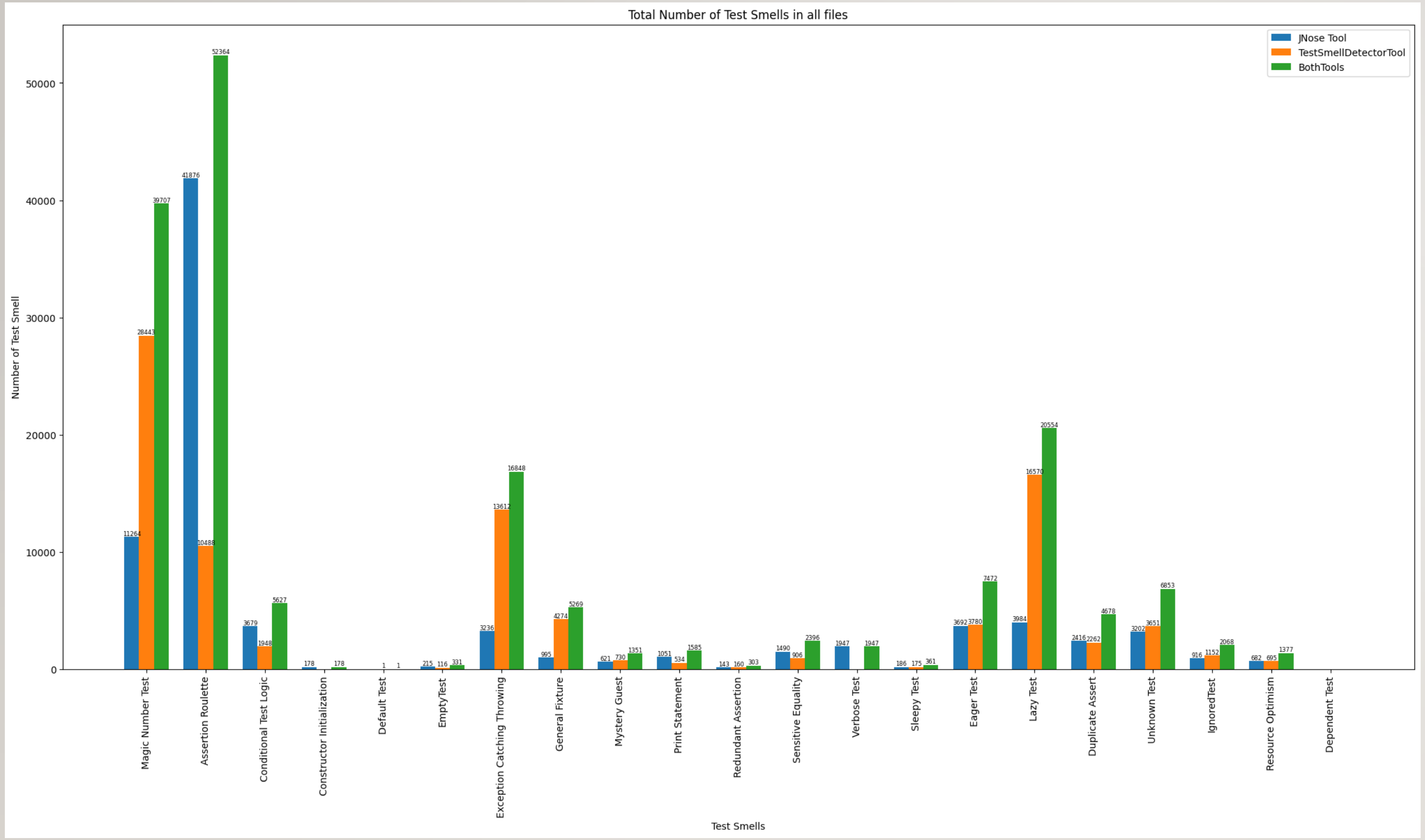


Figure 18: Total Number of Test Smells with using JNose and TestSmellDetector Tools in all files

DISCUSSION - TOTAL NUMBER OF TEST SMELLS

- For 'Magic Number Test', there can be usages of hardcoded, unexplained numeric values, which can easily slip into code.
- For 'Eager Test', there are trials to check too many functionalities at once, which is a typical result of trying to reduce the number of test methods without considering the isolation of functionalities.

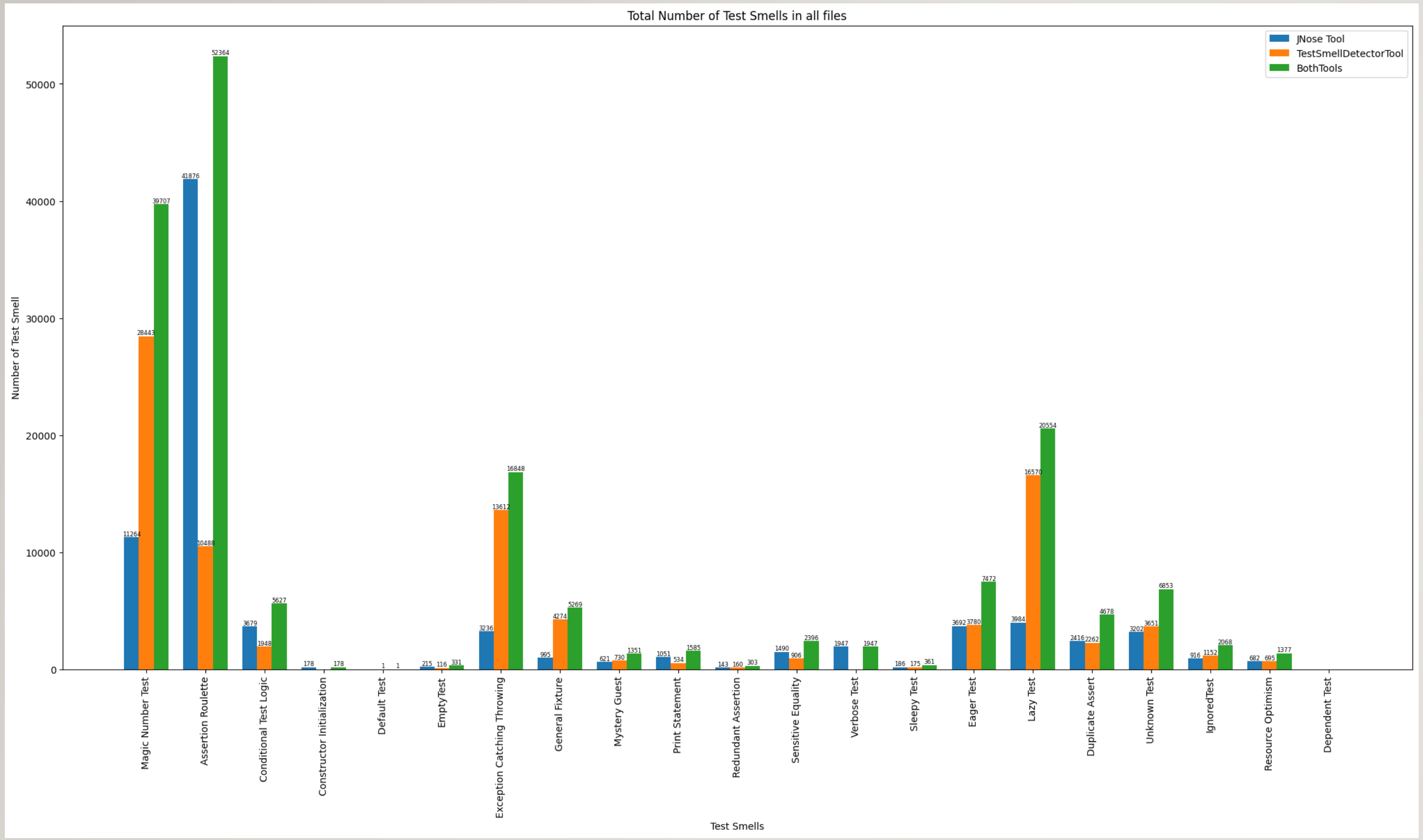
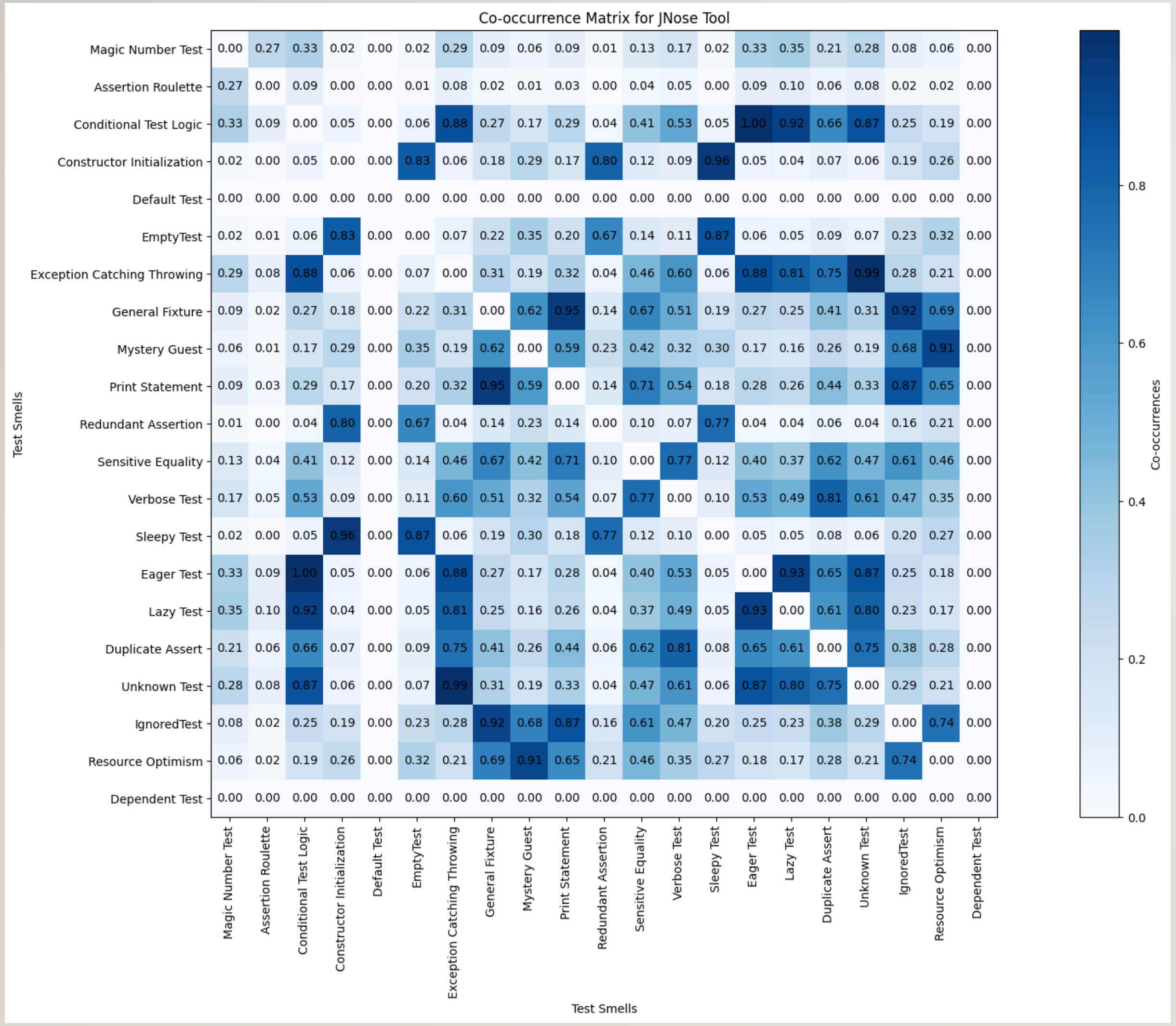


Figure 19: Total Number of Test Smells with using JNose and TestSmellDetector Tools in all files

DISCUSSION - TOTAL NUMBER OF TEST SMELLS

- For 'Lazy Test', there are not fully coverages for the expected functionalities, often because tests are not updated to reflect changes in the application's requirements or functionality.
- For 'Exception Catching Throwing', there can be improper handlings or testing of exceptions. The test may fail to sufficiently assert the throwing of exceptions or might overly generalize exception handling, catching more than it should.

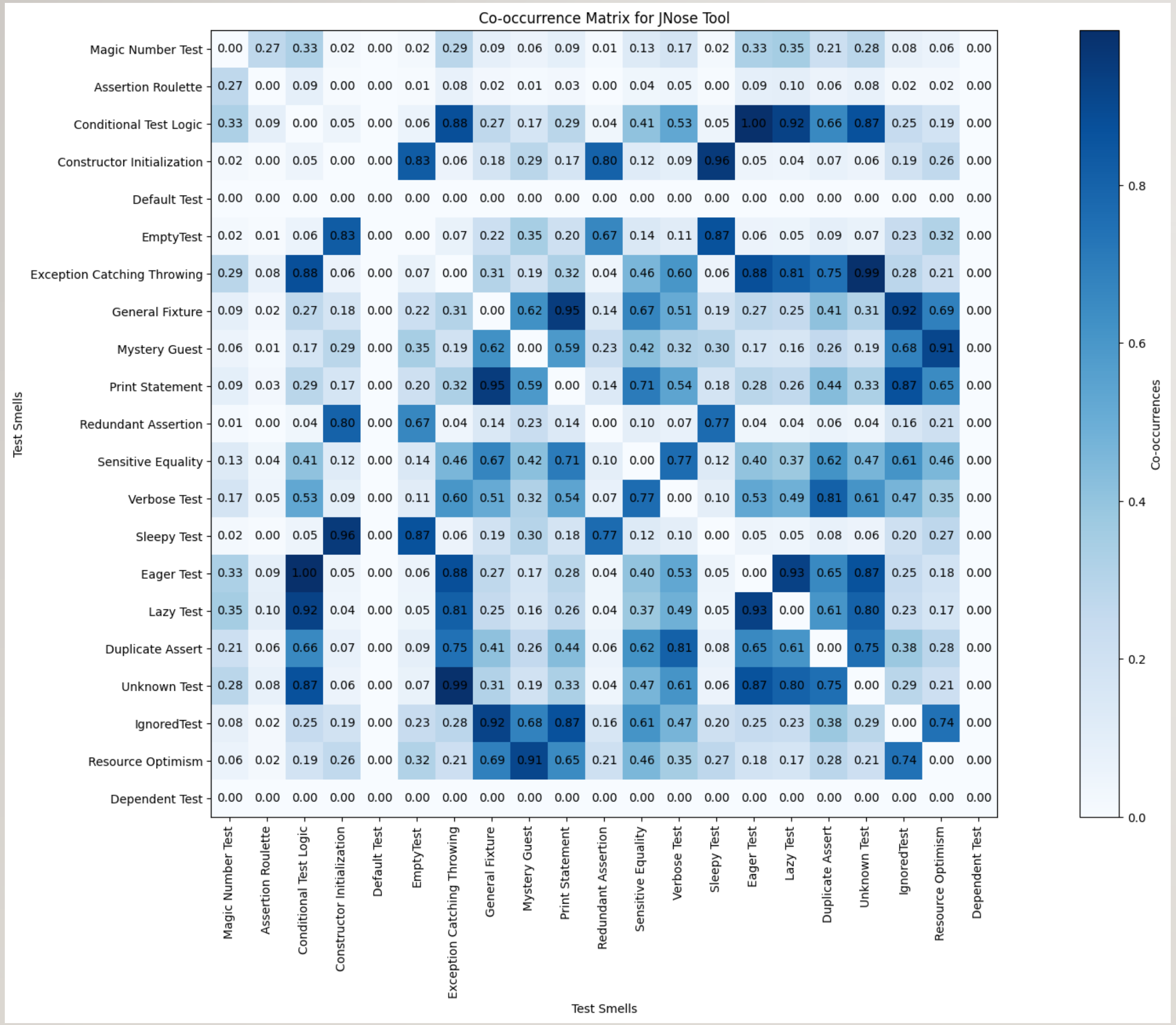


Test Smells	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.27	0.33	0.02	0.00	0.02	0.29	0.09	0.06	0.09	0.01	0.13	0.17	0.02	0.33	0.35	0.21	0.28	0.08	0.06	0.00
Assertion Roulette	0.27	0.00	0.09	0.00	0.00	0.01	0.08	0.02	0.01	0.03	0.00	0.04	0.05	0.00	0.09	0.10	0.06	0.08	0.02	0.02	0.00
Conditional Test Logic	0.33	0.09	0.00	0.05	0.00	0.06	0.88	0.27	0.17	0.29	0.04	0.41	0.53	0.05	1.00	0.92	0.66	0.87	0.25	0.19	0.00
Constructor Initialization	0.02	0.00	0.05	0.00	0.00	0.83	0.06	0.18	0.29	0.17	0.80	0.12	0.09	0.96	0.05	0.04	0.07	0.06	0.19	0.26	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.02	0.01	0.06	0.83	0.00	0.00	0.07	0.22	0.35	0.20	0.67	0.14	0.11	0.87	0.06	0.05	0.09	0.07	0.23	0.32	0.00
Exception Catching Throwing	0.29	0.08	0.88	0.06	0.00	0.07	0.00	0.31	0.19	0.32	0.04	0.46	0.60	0.06	0.88	0.81	0.75	0.99	0.28	0.21	0.00
General Fixture	0.09	0.02	0.27	0.18	0.00	0.22	0.31	0.00	0.62	0.95	0.14	0.67	0.51	0.19	0.27	0.25	0.41	0.31	0.92	0.69	0.00
Mystery Guest	0.06	0.01	0.17	0.29	0.00	0.35	0.19	0.62	0.00	0.59	0.23	0.42	0.32	0.30	0.17	0.16	0.26	0.19	0.68	0.91	0.00
Print Statement	0.09	0.03	0.29	0.17	0.00	0.20	0.32	0.95	0.59	0.00	0.14	0.71	0.54	0.18	0.28	0.26	0.44	0.33	0.87	0.65	0.00
Redundant Assertion	0.01	0.00	0.04	0.80	0.00	0.67	0.04	0.14	0.23	0.14	0.00	0.10	0.07	0.77	0.04	0.04	0.06	0.04	0.16	0.21	0.00
Sensitive Equality	0.13	0.04	0.41	0.12	0.00	0.14	0.46	0.67	0.42	0.71	0.10	0.00	0.77	0.12	0.40	0.37	0.62	0.47	0.61	0.46	0.00
Verbose Test	0.17	0.05	0.53	0.09	0.00	0.11	0.60	0.51	0.32	0.54	0.07	0.77	0.00	0.10	0.53	0.49	0.81	0.61	0.47	0.35	0.00
Sleepy Test	0.02	0.00	0.05	0.96	0.00	0.87	0.06	0.19	0.30	0.18	0.77	0.12	0.10	0.00	0.05	0.05	0.08	0.06	0.20	0.27	0.00
Eager Test	0.33	0.09	1.00	0.05	0.00	0.06	0.88	0.27	0.17	0.28	0.04	0.40	0.53	0.05	0.00	0.93	0.65	0.87	0.25	0.18	0.00
Lazy Test	0.35	0.10	0.92	0.04	0.00	0.05	0.81	0.25	0.16	0.26	0.04	0.37	0.49	0.05	0.93	0.00	0.61	0.80	0.23	0.17	0.00
Duplicate Assert	0.21	0.06	0.66	0.07	0.00	0.09	0.75	0.41	0.26	0.44	0.06	0.62	0.81	0.08	0.65	0.61	0.00	0.75	0.38	0.28	0.00
Unknown Test	0.28	0.08	0.87	0.06	0.00	0.07	0.99	0.31	0.19	0.33	0.04	0.47	0.61	0.06	0.87	0.80	0.75	0.00	0.29	0.21	0.00
IgnoredTest	0.08	0.02	0.25	0.19	0.00	0.23	0.28	0.92	0.68	0.87	0.16	0.61	0.47	0.20	0.25	0.23	0.38	0.29	0.00	0.74	0.00
Resource Optimism	0.06	0.02	0.19	0.26	0.00	0.32	0.21	0.69	0.91	0.65	0.21	0.46	0.35	0.27	0.18	0.17	0.28	0.21	0.74	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 20: Co-occurrence Matrix for JNose Tool

DISCUSSION - CO-OCCURRENCE OF TEST SMELLS BASED ON JNOSE TOOL

- Following co-occurence rates are high and reasons can be:
- For 'Conditional Test Logic' and 'Eager Test':
  - By nature of Conditional Test Logic that test cases will cover multiple possible results.
  - Like this often tries to establish so many things at once sets it up to be identified as an 'Eager Test.'.

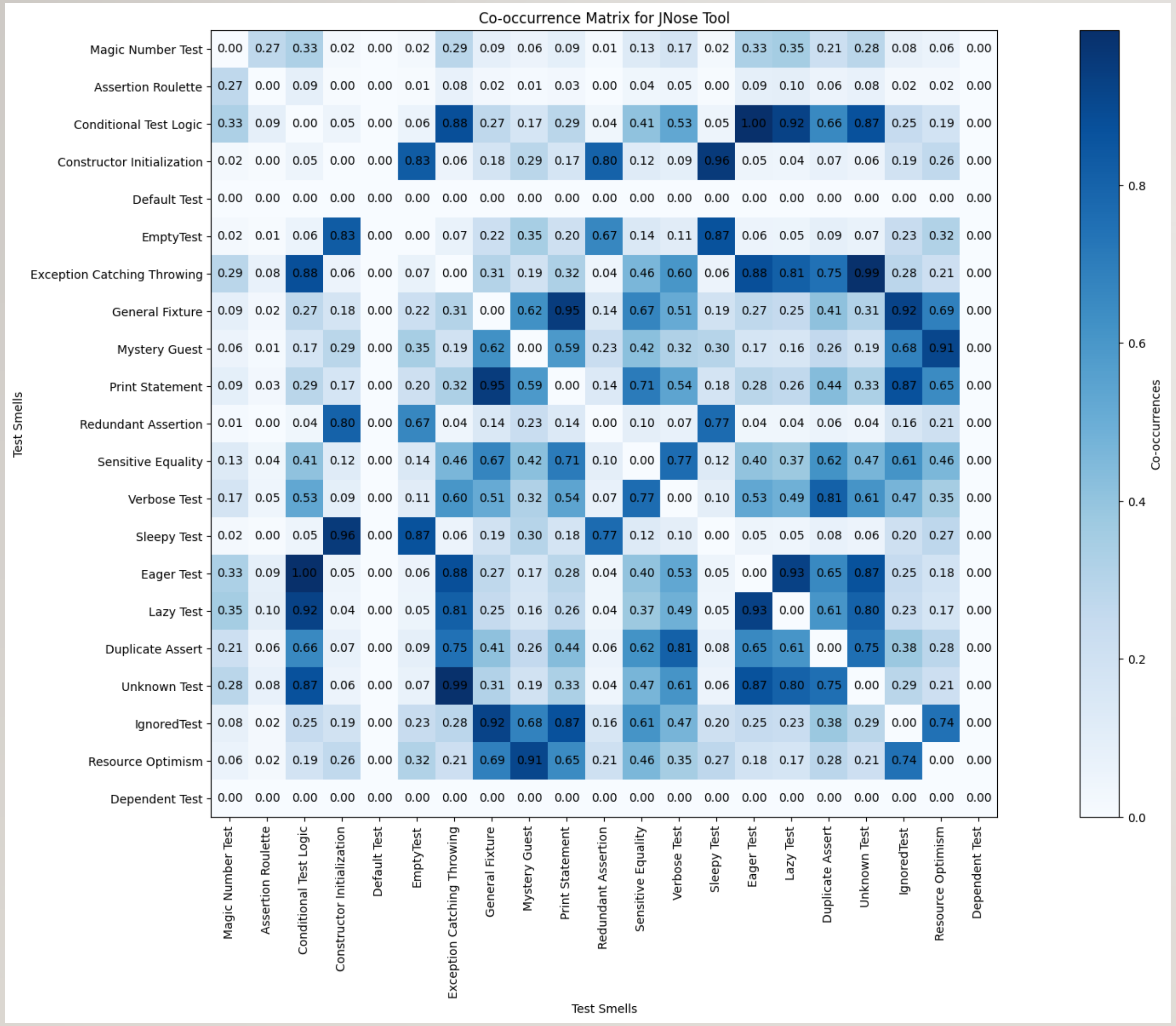


	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.27	0.33	0.02	0.00	0.02	0.29	0.09	0.06	0.09	0.01	0.13	0.17	0.02	0.33	0.35	0.21	0.28	0.08	0.06	0.00
Assertion Roulette	0.27	0.00	0.09	0.00	0.00	0.01	0.08	0.02	0.01	0.03	0.00	0.04	0.05	0.00	0.09	0.10	0.06	0.08	0.02	0.02	0.00
Conditional Test Logic	0.33	0.09	0.00	0.05	0.00	0.06	0.88	0.27	0.17	0.29	0.04	0.41	0.53	0.05	1.00	0.92	0.66	0.87	0.25	0.19	0.00
Constructor Initialization	0.02	0.00	0.05	0.00	0.00	0.83	0.06	0.18	0.29	0.17	0.80	0.12	0.09	0.96	0.05	0.04	0.07	0.06	0.19	0.26	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.02	0.01	0.06	0.83	0.00	0.00	0.07	0.22	0.35	0.20	0.67	0.14	0.11	0.87	0.06	0.05	0.09	0.07	0.23	0.32	0.00
Exception Catching Throwing	0.29	0.08	0.88	0.06	0.00	0.07	0.00	0.31	0.19	0.32	0.04	0.46	0.60	0.06	0.88	0.81	0.75	0.99	0.28	0.21	0.00
General Fixture	0.09	0.02	0.27	0.18	0.00	0.22	0.31	0.00	0.62	0.95	0.14	0.67	0.51	0.19	0.27	0.25	0.41	0.31	0.92	0.69	0.00
Mystery Guest	0.06	0.01	0.17	0.29	0.00	0.35	0.19	0.62	0.00	0.59	0.23	0.42	0.32	0.30	0.17	0.16	0.26	0.19	0.68	0.91	0.00
Print Statement	0.09	0.03	0.29	0.17	0.00	0.20	0.32	0.95	0.59	0.00	0.14	0.71	0.54	0.18	0.28	0.26	0.44	0.33	0.87	0.65	0.00
Redundant Assertion	0.01	0.00	0.04	0.80	0.00	0.67	0.04	0.14	0.23	0.14	0.00	0.10	0.07	0.77	0.04	0.04	0.06	0.04	0.16	0.21	0.00
Sensitive Equality	0.13	0.04	0.41	0.12	0.00	0.14	0.46	0.67	0.42	0.71	0.10	0.00	0.77	0.12	0.40	0.37	0.62	0.47	0.61	0.46	0.00
Verbose Test	0.17	0.05	0.53	0.09	0.00	0.11	0.60	0.51	0.32	0.54	0.07	0.77	0.00	0.10	0.53	0.49	0.81	0.61	0.47	0.35	0.00
Sleepy Test	0.02	0.00	0.05	0.96	0.00	0.87	0.06	0.19	0.30	0.18	0.77	0.12	0.10	0.00	0.05	0.05	0.08	0.06	0.20	0.27	0.00
Eager Test	0.33	0.09	1.00	0.05	0.00	0.06	0.88	0.27	0.17	0.28	0.04	0.40	0.53	0.05	0.00	0.93	0.65	0.87	0.25	0.18	0.00
Lazy Test	0.35	0.10	0.92	0.04	0.00	0.05	0.81	0.25	0.16	0.26	0.04	0.37	0.49	0.05	0.93	0.00	0.61	0.80	0.23	0.17	0.00
Duplicate Assert	0.21	0.06	0.66	0.07	0.00	0.09	0.75	0.41	0.26	0.44	0.06	0.62	0.81	0.08	0.65	0.61	0.00	0.75	0.38	0.28	0.00
Unknown Test	0.28	0.08	0.87	0.06	0.00	0.07	0.99	0.31	0.19	0.33	0.04	0.47	0.61	0.06	0.87	0.80	0.75	0.00	0.29	0.21	0.00
IgnoredTest	0.08	0.02	0.25	0.19	0.00	0.23	0.28	0.92	0.68	0.87	0.16	0.61	0.47	0.20	0.25	0.23	0.38	0.29	0.00	0.74	0.00
Resource Optimism	0.06	0.02	0.19	0.26	0.00	0.32	0.21	0.69	0.91	0.65	0.21	0.46	0.35	0.27	0.18	0.17	0.28	0.21	0.74	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 21: Co-occurrence Matrix for JNose Tool

DISCUSSION - CO-OCCURRENCE OF TEST SMELLS BASED ON JNOSE TOOL

- For 'Exception Catching Throwing' with 'Unknown Test':
  - They are overlap because of a lack of specificity and intentionality in test design.
  - Also, poor test design, inadequate documentation, and the tendency to apply quick fixes under pressure.

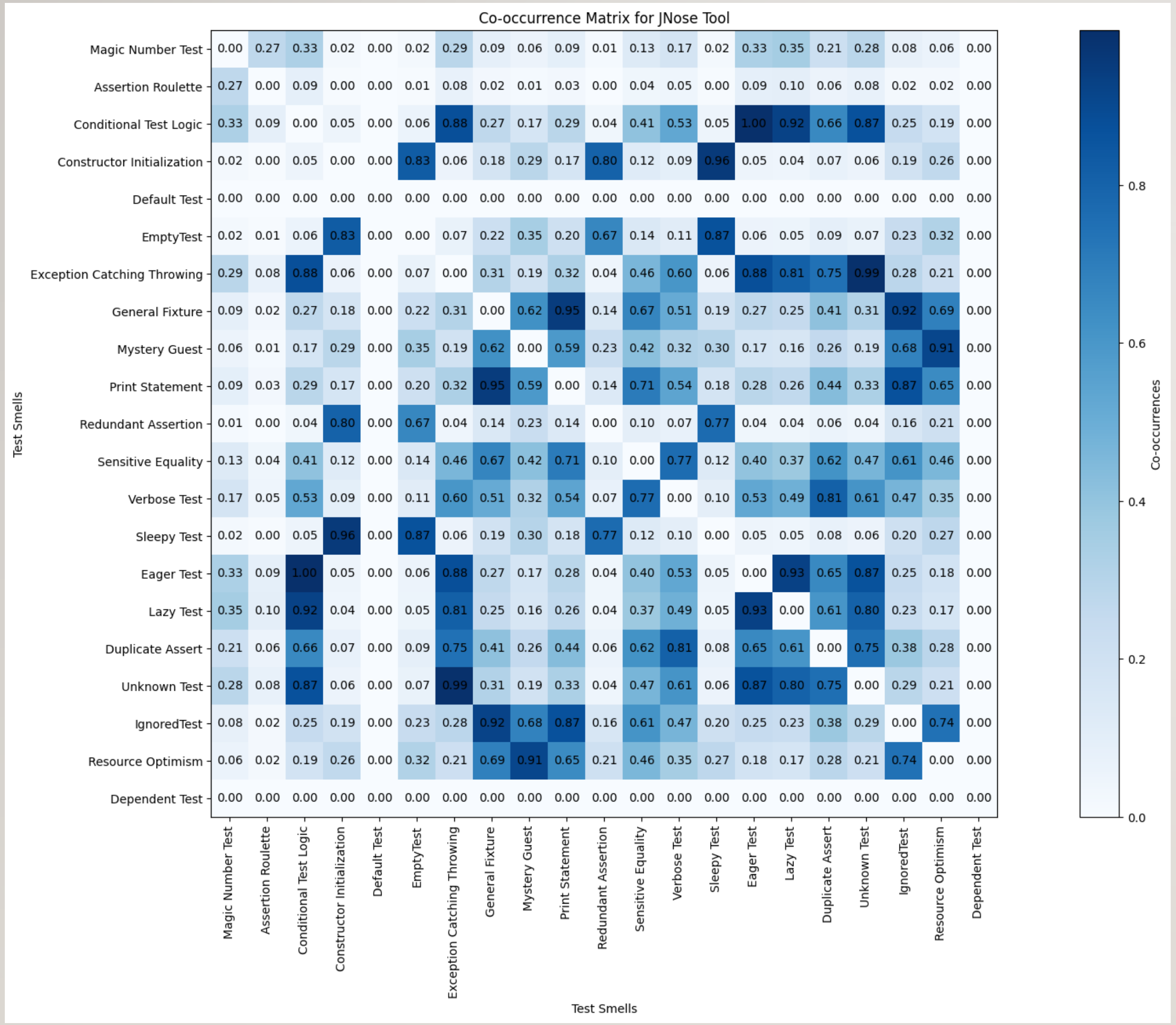


	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.27	0.33	0.02	0.00	0.02	0.29	0.09	0.06	0.09	0.01	0.13	0.17	0.02	0.33	0.35	0.21	0.28	0.08	0.06	0.00
Assertion Roulette	0.27	0.00	0.09	0.00	0.00	0.01	0.08	0.02	0.01	0.03	0.00	0.04	0.05	0.00	0.09	0.10	0.06	0.08	0.02	0.02	0.00
Conditional Test Logic	0.33	0.09	0.00	0.05	0.00	0.06	0.88	0.27	0.17	0.29	0.04	0.41	0.53	0.05	1.00	0.92	0.66	0.87	0.25	0.19	0.00
Constructor Initialization	0.02	0.00	0.05	0.00	0.00	0.83	0.06	0.18	0.29	0.17	0.80	0.12	0.09	0.96	0.05	0.04	0.07	0.06	0.19	0.26	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.02	0.01	0.06	0.83	0.00	0.00	0.07	0.22	0.35	0.20	0.67	0.14	0.11	0.87	0.06	0.05	0.09	0.07	0.23	0.32	0.00
Exception Catching Throwing	0.29	0.08	0.88	0.06	0.00	0.07	0.00	0.31	0.19	0.32	0.04	0.46	0.60	0.06	0.88	0.81	0.75	0.99	0.28	0.21	0.00
General Fixture	0.09	0.02	0.27	0.18	0.00	0.22	0.31	0.00	0.62	0.95	0.14	0.67	0.51	0.19	0.27	0.25	0.41	0.31	0.92	0.69	0.00
Mystery Guest	0.06	0.01	0.17	0.29	0.00	0.35	0.19	0.62	0.00	0.59	0.23	0.42	0.32	0.30	0.17	0.16	0.26	0.19	0.68	0.91	0.00
Print Statement	0.09	0.03	0.29	0.17	0.00	0.20	0.32	0.95	0.59	0.00	0.14	0.71	0.54	0.18	0.28	0.26	0.44	0.33	0.87	0.65	0.00
Redundant Assertion	0.01	0.00	0.04	0.80	0.00	0.67	0.04	0.14	0.23	0.14	0.00	0.10	0.07	0.77	0.04	0.04	0.06	0.04	0.16	0.21	0.00
Sensitive Equality	0.13	0.04	0.41	0.12	0.00	0.14	0.46	0.67	0.42	0.71	0.10	0.00	0.77	0.12	0.40	0.37	0.62	0.47	0.61	0.46	0.00
Verbose Test	0.17	0.05	0.53	0.09	0.00	0.11	0.60	0.51	0.32	0.54	0.07	0.77	0.00	0.10	0.53	0.49	0.81	0.61	0.47	0.35	0.00
Sleepy Test	0.02	0.00	0.05	0.96	0.00	0.87	0.06	0.19	0.30	0.18	0.77	0.12	0.10	0.00	0.05	0.05	0.08	0.06	0.20	0.27	0.00
Eager Test	0.33	0.09	1.00	0.05	0.00	0.06	0.88	0.27	0.17	0.28	0.04	0.40	0.53	0.05	0.00	0.93	0.65	0.87	0.25	0.18	0.00
Lazy Test	0.35	0.10	0.92	0.04	0.00	0.05	0.81	0.25	0.16	0.26	0.04	0.37	0.49	0.05	0.93	0.00	0.61	0.80	0.23	0.17	0.00
Duplicate Assert	0.21	0.06	0.66	0.07	0.00	0.09	0.75	0.41	0.26	0.44	0.06	0.62	0.81	0.08	0.65	0.61	0.00	0.75	0.38	0.28	0.00
Unknown Test	0.28	0.08	0.87	0.06	0.00	0.07	0.99	0.31	0.19	0.33	0.04	0.47	0.61	0.06	0.87	0.80	0.75	0.00	0.29	0.21	0.00
IgnoredTest	0.08	0.02	0.25	0.19	0.00	0.23	0.28	0.92	0.68	0.87	0.16	0.61	0.47	0.20	0.25	0.23	0.38	0.29	0.00	0.74	0.00
Resource Optimism	0.06	0.02	0.19	0.26	0.00	0.32	0.21	0.69	0.91	0.65	0.21	0.46	0.35	0.27	0.18	0.17	0.28	0.21	0.74	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 22: Co-occurrence Matrix for JNose Tool

DISCUSSION - CO-OCCURRENCE OF TEST SMELLS BASED ON JNOSE TOOL

- For 'Sleepy Test' and 'Constructor Initialization':
  - The common denominator is a combination of insufficient handling of test setup.
  - Also test codes have a lack of understanding or utilization of more robust synchronization and initialization mechanisms.



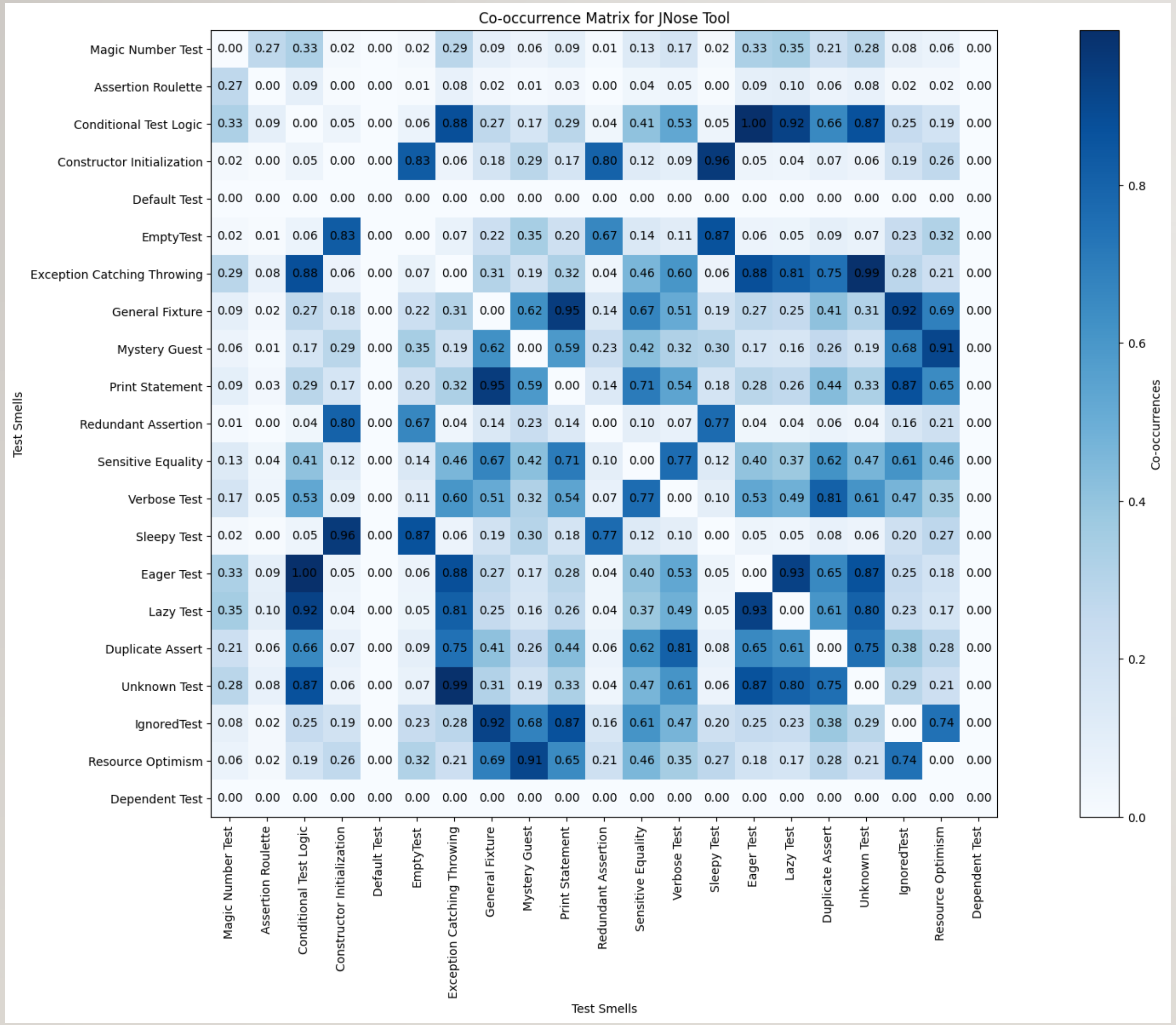
Test Smells	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.27	0.33	0.02	0.00	0.02	0.29	0.09	0.06	0.09	0.01	0.13	0.17	0.02	0.33	0.35	0.21	0.28	0.08	0.06	0.00
Assertion Roulette	0.27	0.00	0.09	0.00	0.00	0.01	0.08	0.02	0.01	0.03	0.00	0.04	0.05	0.00	0.09	0.10	0.06	0.08	0.02	0.02	0.00
Conditional Test Logic	0.33	0.09	0.00	0.05	0.00	0.06	0.88	0.27	0.17	0.29	0.04	0.41	0.53	0.05	1.00	0.92	0.66	0.87	0.25	0.19	0.00
Constructor Initialization	0.02	0.00	0.05	0.00	0.00	0.83	0.06	0.18	0.29	0.17	0.80	0.12	0.09	0.96	0.05	0.04	0.07	0.06	0.19	0.26	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.02	0.01	0.06	0.83	0.00	0.00	0.07	0.22	0.35	0.20	0.67	0.14	0.11	0.87	0.06	0.05	0.09	0.07	0.23	0.32	0.00
Exception Catching Throwing	0.29	0.08	0.88	0.06	0.00	0.07	0.00	0.31	0.19	0.32	0.04	0.46	0.60	0.06	0.88	0.81	0.75	0.99	0.28	0.21	0.00
General Fixture	0.09	0.02	0.27	0.18	0.00	0.22	0.31	0.00	0.62	0.95	0.14	0.67	0.51	0.19	0.27	0.25	0.41	0.31	0.92	0.69	0.00
Mystery Guest	0.06	0.01	0.17	0.29	0.00	0.35	0.19	0.62	0.00	0.59	0.23	0.42	0.32	0.30	0.17	0.16	0.26	0.19	0.68	0.91	0.00
Print Statement	0.09	0.03	0.29	0.17	0.00	0.20	0.32	0.95	0.59	0.00	0.14	0.71	0.54	0.18	0.28	0.26	0.44	0.33	0.87	0.65	0.00
Redundant Assertion	0.01	0.00	0.04	0.80	0.00	0.67	0.04	0.14	0.23	0.14	0.00	0.10	0.07	0.77	0.04	0.04	0.06	0.04	0.16	0.21	0.00
Sensitive Equality	0.13	0.04	0.41	0.12	0.00	0.14	0.46	0.67	0.42	0.71	0.10	0.00	0.77	0.12	0.40	0.37	0.62	0.47	0.61	0.46	0.00
Verbose Test	0.17	0.05	0.53	0.09	0.00	0.11	0.60	0.51	0.32	0.54	0.07	0.77	0.00	0.10	0.53	0.49	0.81	0.61	0.47	0.35	0.00
Sleepy Test	0.02	0.00	0.05	0.96	0.00	0.87	0.06	0.19	0.30	0.18	0.77	0.12	0.10	0.00	0.05	0.05	0.08	0.06	0.20	0.27	0.00
Eager Test	0.33	0.09	1.00	0.05	0.00	0.06	0.88	0.27	0.17	0.28	0.04	0.40	0.53	0.05	0.00	0.93	0.65	0.87	0.25	0.18	0.00
Lazy Test	0.35	0.10	0.92	0.04	0.00	0.05	0.81	0.25	0.16	0.26	0.04	0.37	0.49	0.05	0.93	0.00	0.61	0.80	0.23	0.17	0.00
Duplicate Assert	0.21	0.06	0.66	0.07	0.00	0.09	0.75	0.41	0.26	0.44	0.06	0.62	0.81	0.08	0.65	0.61	0.00	0.75	0.38	0.28	0.00
Unknown Test	0.28	0.08	0.87	0.06	0.00	0.07	0.99	0.31	0.19	0.33	0.04	0.47	0.61	0.06	0.87	0.80	0.75	0.00	0.29	0.21	0.00
IgnoredTest	0.08	0.02	0.25	0.19	0.00	0.23	0.28	0.92	0.68	0.87	0.16	0.61	0.47	0.20	0.25	0.23	0.38	0.29	0.00	0.74	0.00
Resource Optimism	0.06	0.02	0.19	0.26	0.00	0.32	0.21	0.69	0.91	0.65	0.21	0.46	0.35	0.27	0.18	0.17	0.28	0.21	0.74	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 23: Co-occurrence Matrix for JNose Tool

DISCUSSION - CO-OCCURRENCE OF TEST SMELLS BASED ON JNOSE TOOL

- Following co-occurence rates are low and reasons can be:
- For 'Magic Number Test' and 'Redundant Assertion’:
  - Magic numbers often result from a lack of documentation or understanding of the code, while redundant assertions tend to from copy-pasting test code without proper refinement.
  - The presence of magic numbers does not require or logically lead to redundant assertions

DISCUSSION - CO-OCCURRENCE OF TEST SMELLS BASED ON JNOSE TOOL

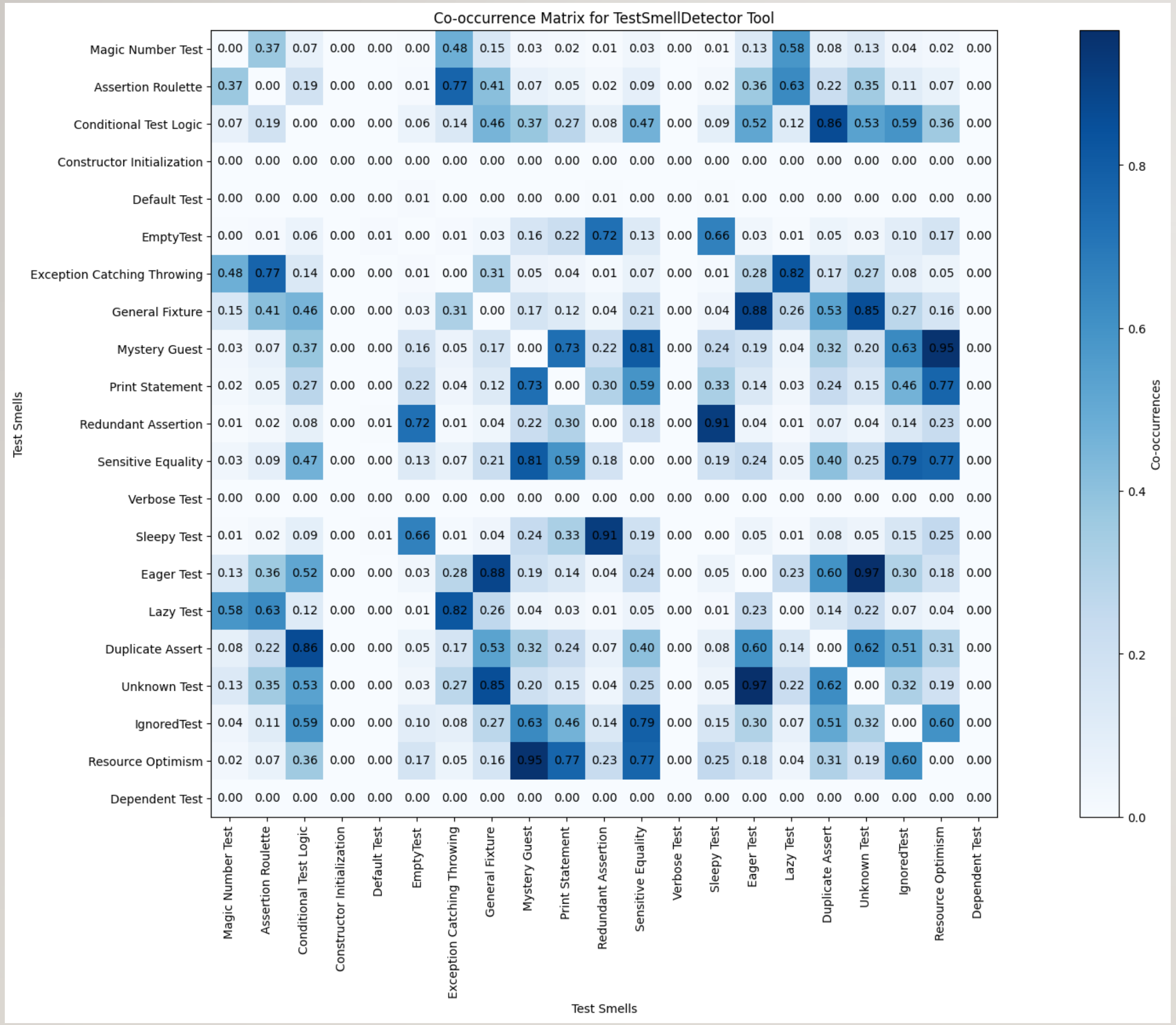


Test Smells	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.27	0.33	0.02	0.00	0.02	0.29	0.09	0.06	0.09	0.01	0.13	0.17	0.02	0.33	0.35	0.21	0.28	0.08	0.06	0.00
Assertion Roulette	0.27	0.00	0.09	0.00	0.00	0.01	0.08	0.02	0.01	0.03	0.00	0.04	0.05	0.00	0.09	0.10	0.06	0.08	0.02	0.02	0.00
Conditional Test Logic	0.33	0.09	0.00	0.05	0.00	0.06	0.88	0.27	0.17	0.29	0.04	0.41	0.53	0.05	1.00	0.92	0.66	0.87	0.25	0.19	0.00
Constructor Initialization	0.02	0.00	0.05	0.00	0.00	0.83	0.06	0.18	0.29	0.17	0.80	0.12	0.09	0.96	0.05	0.04	0.07	0.06	0.19	0.26	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.02	0.01	0.06	0.83	0.00	0.00	0.07	0.22	0.35	0.20	0.67	0.14	0.11	0.87	0.06	0.05	0.09	0.07	0.23	0.32	0.00
Exception Catching Throwing	0.29	0.08	0.88	0.06	0.00	0.07	0.00	0.31	0.19	0.32	0.04	0.46	0.60	0.06	0.88	0.81	0.75	0.99	0.28	0.21	0.00
General Fixture	0.09	0.02	0.27	0.18	0.00	0.22	0.31	0.00	0.62	0.95	0.14	0.67	0.51	0.19	0.27	0.25	0.41	0.31	0.92	0.69	0.00
Mystery Guest	0.06	0.01	0.17	0.29	0.00	0.35	0.19	0.62	0.00	0.59	0.23	0.42	0.32	0.30	0.17	0.16	0.26	0.19	0.68	0.91	0.00
Print Statement	0.09	0.03	0.29	0.17	0.00	0.20	0.32	0.95	0.59	0.00	0.14	0.71	0.54	0.18	0.28	0.26	0.44	0.33	0.87	0.65	0.00
Redundant Assertion	0.01	0.00	0.04	0.80	0.00	0.67	0.04	0.14	0.23	0.14	0.00	0.10	0.07	0.77	0.04	0.04	0.06	0.04	0.16	0.21	0.00
Sensitive Equality	0.13	0.04	0.41	0.12	0.00	0.14	0.46	0.67	0.42	0.71	0.10	0.00	0.77	0.12	0.40	0.37	0.62	0.47	0.61	0.46	0.00
Verbose Test	0.17	0.05	0.53	0.09	0.00	0.11	0.60	0.51	0.32	0.54	0.07	0.77	0.00	0.10	0.53	0.49	0.81	0.61	0.47	0.35	0.00
Sleepy Test	0.02	0.00	0.05	0.96	0.00	0.87	0.06	0.19	0.30	0.18	0.77	0.12	0.10	0.00	0.05	0.05	0.08	0.06	0.20	0.27	0.00
Eager Test	0.33	0.09	1.00	0.05	0.00	0.06	0.88	0.27	0.17	0.28	0.04	0.40	0.53	0.05	0.00	0.93	0.65	0.87	0.25	0.18	0.00
Lazy Test	0.35	0.10	0.92	0.04	0.00	0.05	0.81	0.25	0.16	0.26	0.04	0.37	0.49	0.05	0.93	0.00	0.61	0.80	0.23	0.17	0.00
Duplicate Assert	0.21	0.06	0.66	0.07	0.00	0.09	0.75	0.41	0.26	0.44	0.06	0.62	0.81	0.08	0.65	0.61	0.00	0.75	0.38	0.28	0.00
Unknown Test	0.28	0.08	0.87	0.06	0.00	0.07	0.99	0.31	0.19	0.33	0.04	0.47	0.61	0.06	0.87	0.80	0.75	0.00	0.29	0.21	0.00
IgnoredTest	0.08	0.02	0.25	0.19	0.00	0.23	0.28	0.92	0.68	0.87	0.16	0.61	0.47	0.20	0.25	0.23	0.38	0.29	0.00	0.74	0.00
Resource Optimism	0.06	0.02	0.19	0.26	0.00	0.32	0.21	0.69	0.91	0.65	0.21	0.46	0.35	0.27	0.18	0.17	0.28	0.21	0.74	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 24: Co-occurrence Matrix for JNose Tool

- Both co-occurence of 'Mystery Guest' and 'Assertion Roulette' and, 'Empty Test' and 'Assertion Roulette’ are low because and the reason can be:
  - 'Mystery Guest' deals with unclear test dependencies, while 'Assertion Roulette' concerns the clarity of the assertions within the test.
  - Both 'Empty Test' and 'Assertion Roulette' cannot co-occur simply because an 'Empty Test' has no assertions, and therefore cannot create a situation where it's unclear which assertion might fail.

DISCUSSION - CO-OCCURRENCE OF TEST SMELLS BASED ON TESTSMELLDETECTOR TOOL



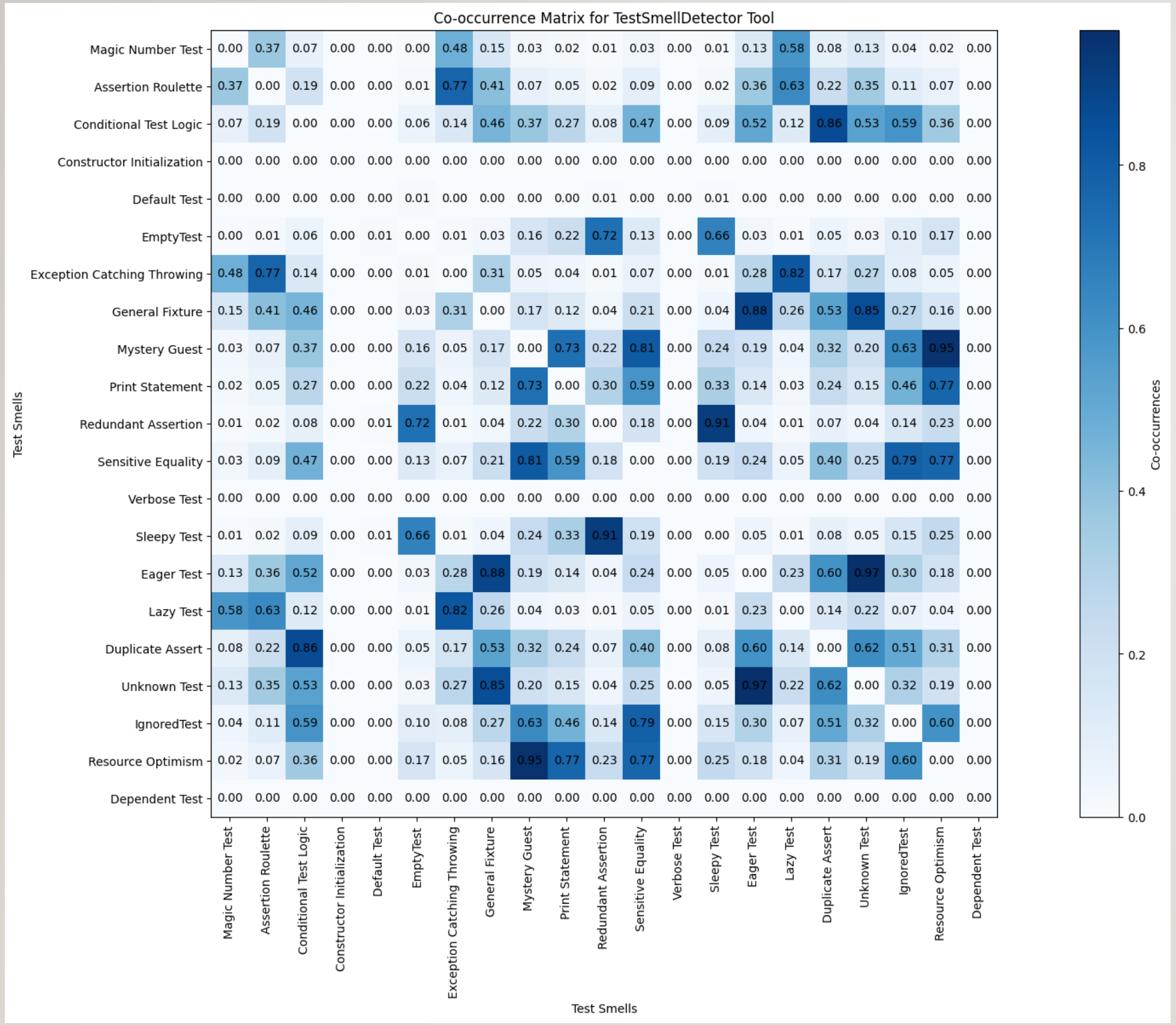
Test Smells	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.37	0.07	0.00	0.00	0.00	0.48	0.15	0.03	0.02	0.01	0.03	0.00	0.01	0.13	0.58	0.08	0.13	0.04	0.02	0.00
Assertion Roulette	0.37	0.00	0.19	0.00	0.00	0.01	0.77	0.41	0.07	0.05	0.02	0.09	0.00	0.02	0.36	0.63	0.22	0.35	0.11	0.07	0.00
Conditional Test Logic	0.07	0.19	0.00	0.00	0.00	0.06	0.14	0.46	0.37	0.27	0.08	0.47	0.00	0.09	0.52	0.12	0.86	0.53	0.59	0.36	0.00
Constructor Initialization	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.00	0.01	0.06	0.00	0.01	0.00	0.01	0.03	0.16	0.22	0.72	0.13	0.00	0.66	0.03	0.01	0.05	0.03	0.10	0.17	0.00
Exception Catching Throwing	0.48	0.77	0.14	0.00	0.00	0.01	0.00	0.31	0.05	0.04	0.01	0.07	0.00	0.01	0.28	0.82	0.17	0.27	0.08	0.05	0.00
General Fixture	0.15	0.41	0.46	0.00	0.00	0.03	0.31	0.00	0.17	0.12	0.04	0.21	0.00	0.04	0.88	0.26	0.53	0.85	0.27	0.16	0.00
Mystery Guest	0.03	0.07	0.37	0.00	0.00	0.16	0.05	0.17	0.00	0.73	0.22	0.81	0.00	0.24	0.19	0.04	0.32	0.20	0.63	0.95	0.00
Print Statement	0.02	0.05	0.27	0.00	0.00	0.22	0.04	0.12	0.73	0.00	0.30	0.59	0.00	0.33	0.14	0.03	0.24	0.15	0.46	0.77	0.00
Redundant Assertion	0.01	0.02	0.08	0.00	0.01	0.72	0.01	0.04	0.22	0.30	0.00	0.18	0.00	0.91	0.04	0.01	0.07	0.04	0.14	0.23	0.00
Sensitive Equality	0.03	0.09	0.47	0.00	0.00	0.13	0.07	0.21	0.81	0.59	0.18	0.00	0.00	0.19	0.24	0.05	0.40	0.25	0.79	0.77	0.00
Verbose Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sleepy Test	0.01	0.02	0.09	0.00	0.01	0.66	0.01	0.04	0.24	0.33	0.91	0.19	0.00	0.00	0.05	0.01	0.08	0.05	0.15	0.25	0.00
Eager Test	0.13	0.36	0.52	0.00	0.00	0.03	0.28	0.88	0.19	0.14	0.04	0.24	0.00	0.05	0.00	0.23	0.60	0.97	0.30	0.18	0.00
Lazy Test	0.58	0.63	0.12	0.00	0.00	0.01	0.82	0.26	0.04	0.03	0.01	0.05	0.00	0.01	0.23	0.00	0.14	0.22	0.07	0.04	0.00
Duplicate Assert	0.08	0.22	0.86	0.00	0.00	0.05	0.17	0.53	0.32	0.24	0.07	0.40	0.00	0.08	0.60	0.14	0.00	0.62	0.51	0.31	0.00
Unknown Test	0.13	0.35	0.53	0.00	0.00	0.03	0.27	0.85	0.20	0.15	0.04	0.25	0.00	0.05	0.97	0.22	0.62	0.00	0.32	0.19	0.00
IgnoredTest	0.04	0.11	0.59	0.00	0.00	0.10	0.08	0.27	0.63	0.46	0.14	0.79	0.00	0.15	0.30	0.07	0.51	0.32	0.00	0.60	0.00
Resource Optimism	0.02	0.07	0.36	0.00	0.00	0.17	0.05	0.16	0.95	0.77	0.23	0.77	0.00	0.25	0.18	0.04	0.31	0.19	0.60	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 25: Co-occurrence Matrix for TestSmellDetector Tool

- Following co-occurence rates are high and reasons can be:
- For 'Unknown Test' and 'Eager Test:
  - 'Unknown Test' naturally serves the purpose of tests that are overextended in the scope 'Eager Test'.

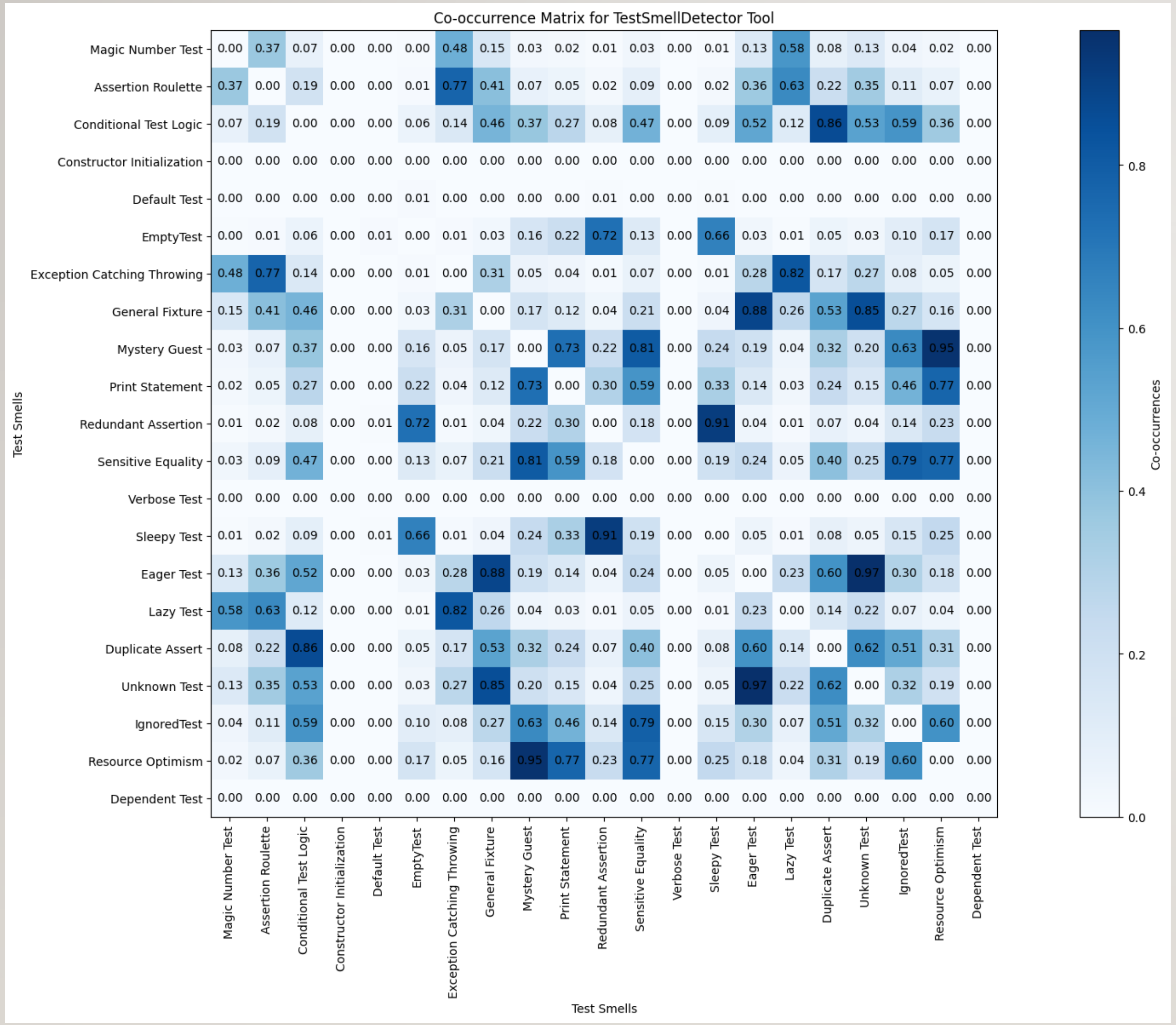
DISCUSSION - CO-OCCURRENCE OF TEST SMELLS BASED ON TESTSMELLDETECTOR TOOL

- For 'Source Optimism' with 'Mystery Guest’
  - Both smells come from a problematic handling of external resources in test cases.



Test Smells	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.37	0.07	0.00	0.00	0.00	0.48	0.15	0.03	0.02	0.01	0.03	0.00	0.01	0.13	0.58	0.08	0.13	0.04	0.02	0.00
Assertion Roulette	0.37	0.00	0.19	0.00	0.00	0.01	0.77	0.41	0.07	0.05	0.02	0.09	0.00	0.02	0.36	0.63	0.22	0.35	0.11	0.07	0.00
Conditional Test Logic	0.07	0.19	0.00	0.00	0.00	0.06	0.14	0.46	0.37	0.27	0.08	0.47	0.00	0.09	0.52	0.12	0.86	0.53	0.59	0.36	0.00
Constructor Initialization	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.00	0.01	0.06	0.00	0.01	0.00	0.01	0.03	0.16	0.22	0.72	0.13	0.00	0.66	0.03	0.01	0.05	0.03	0.10	0.17	0.00
Exception Catching Throwing	0.48	0.77	0.14	0.00	0.00	0.01	0.00	0.31	0.05	0.04	0.01	0.07	0.00	0.01	0.28	0.82	0.17	0.27	0.08	0.05	0.00
General Fixture	0.15	0.41	0.46	0.00	0.00	0.03	0.31	0.00	0.17	0.12	0.04	0.21	0.00	0.04	0.88	0.26	0.53	0.85	0.27	0.16	0.00
Mystery Guest	0.03	0.07	0.37	0.00	0.00	0.16	0.05	0.17	0.00	0.73	0.22	0.81	0.00	0.24	0.19	0.04	0.32	0.20	0.63	0.95	0.00
Print Statement	0.02	0.05	0.27	0.00	0.00	0.22	0.04	0.12	0.73	0.00	0.30	0.59	0.00	0.33	0.14	0.03	0.24	0.15	0.46	0.77	0.00
Redundant Assertion	0.01	0.02	0.08	0.00	0.01	0.72	0.01	0.04	0.22	0.30	0.00	0.18	0.00	0.91	0.04	0.01	0.07	0.04	0.14	0.23	0.00
Sensitive Equality	0.03	0.09	0.47	0.00	0.00	0.13	0.07	0.21	0.81	0.59	0.18	0.00	0.00	0.19	0.24	0.05	0.40	0.25	0.79	0.77	0.00
Verbose Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sleepy Test	0.01	0.02	0.09	0.00	0.01	0.66	0.01	0.04	0.24	0.33	0.91	0.19	0.00	0.00	0.05	0.01	0.08	0.05	0.15	0.25	0.00
Eager Test	0.13	0.36	0.52	0.00	0.00	0.03	0.28	0.88	0.19	0.14	0.04	0.24	0.00	0.05	0.00	0.23	0.60	0.97	0.30	0.18	0.00
Lazy Test	0.58	0.63	0.12	0.00	0.00	0.01	0.82	0.26	0.04	0.03	0.01	0.05	0.00	0.01	0.23	0.00	0.14	0.22	0.07	0.04	0.00
Duplicate Assert	0.08	0.22	0.86	0.00	0.00	0.05	0.17	0.53	0.32	0.24	0.07	0.40	0.00	0.08	0.60	0.14	0.00	0.62	0.51	0.31	0.00
Unknown Test	0.13	0.35	0.53	0.00	0.00	0.03	0.27	0.85	0.20	0.15	0.04	0.25	0.00	0.05	0.97	0.22	0.62	0.00	0.32	0.19	0.00
IgnoredTest	0.04	0.11	0.59	0.00	0.00	0.10	0.08	0.27	0.63	0.46	0.14	0.79	0.00	0.15	0.30	0.07	0.51	0.32	0.00	0.60	0.00
Resource Optimism	0.02	0.07	0.36	0.00	0.00	0.17	0.05	0.16	0.95	0.77	0.23	0.77	0.00	0.25	0.18	0.04	0.31	0.19	0.60	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 26: Co-occurrence Matrix for TestSmellDetector Tool

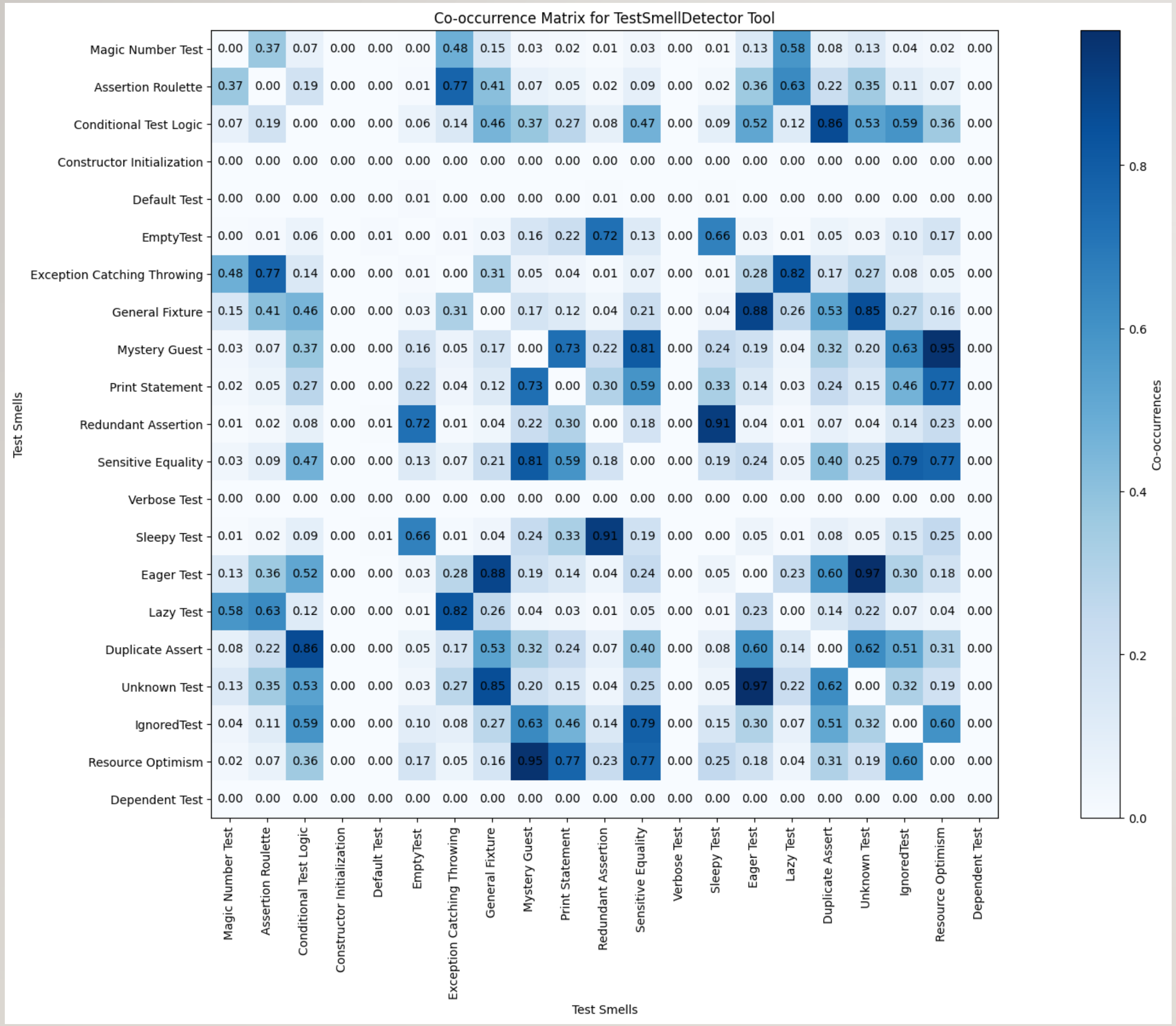


	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.37	0.07	0.00	0.00	0.00	0.48	0.15	0.03	0.02	0.01	0.03	0.00	0.01	0.13	0.58	0.08	0.13	0.04	0.02	0.00
Assertion Roulette	0.37	0.00	0.19	0.00	0.00	0.01	0.77	0.41	0.07	0.05	0.02	0.09	0.00	0.02	0.36	0.63	0.22	0.35	0.11	0.07	0.00
Conditional Test Logic	0.07	0.19	0.00	0.00	0.00	0.06	0.14	0.46	0.37	0.27	0.08	0.47	0.00	0.09	0.52	0.12	0.86	0.53	0.59	0.36	0.00
Constructor Initialization	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.00	0.01	0.06	0.00	0.01	0.00	0.01	0.03	0.16	0.22	0.72	0.13	0.00	0.66	0.03	0.01	0.05	0.03	0.10	0.17	0.00
Exception Catching Throwing	0.48	0.77	0.14	0.00	0.00	0.01	0.00	0.31	0.05	0.04	0.01	0.07	0.00	0.01	0.28	0.82	0.17	0.27	0.08	0.05	0.00
General Fixture	0.15	0.41	0.46	0.00	0.00	0.03	0.31	0.00	0.17	0.12	0.04	0.21	0.00	0.04	0.88	0.26	0.53	0.85	0.27	0.16	0.00
Mystery Guest	0.03	0.07	0.37	0.00	0.00	0.16	0.05	0.17	0.00	0.73	0.22	0.81	0.00	0.24	0.19	0.04	0.32	0.20	0.63	0.95	0.00
Print Statement	0.02	0.05	0.27	0.00	0.00	0.22	0.04	0.12	0.73	0.00	0.30	0.59	0.00	0.33	0.14	0.03	0.24	0.15	0.46	0.77	0.00
Redundant Assertion	0.01	0.02	0.08	0.00	0.01	0.72	0.01	0.04	0.22	0.30	0.00	0.18	0.00	0.91	0.04	0.01	0.07	0.04	0.14	0.23	0.00
Sensitive Equality	0.03	0.09	0.47	0.00	0.00	0.13	0.07	0.21	0.81	0.59	0.18	0.00	0.00	0.19	0.24	0.05	0.40	0.25	0.79	0.77	0.00
Verbose Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sleepy Test	0.01	0.02	0.09	0.00	0.01	0.66	0.01	0.04	0.24	0.33	0.91	0.19	0.00	0.00	0.05	0.01	0.08	0.05	0.15	0.25	0.00
Eager Test	0.13	0.36	0.52	0.00	0.00	0.03	0.28	0.88	0.19	0.14	0.04	0.24	0.00	0.05	0.00	0.23	0.60	0.97	0.30	0.18	0.00
Lazy Test	0.58	0.63	0.12	0.00	0.00	0.01	0.82	0.26	0.04	0.03	0.01	0.05	0.00	0.01	0.23	0.00	0.14	0.22	0.07	0.04	0.00
Duplicate Assert	0.08	0.22	0.86	0.00	0.00	0.05	0.17	0.53	0.32	0.24	0.07	0.40	0.00	0.08	0.60	0.14	0.00	0.62	0.51	0.31	0.00
Unknown Test	0.13	0.35	0.53	0.00	0.00	0.03	0.27	0.85	0.20	0.15	0.04	0.25	0.00	0.05	0.97	0.22	0.62	0.00	0.32	0.19	0.00
IgnoredTest	0.04	0.11	0.59	0.00	0.00	0.10	0.08	0.27	0.63	0.46	0.14	0.79	0.00	0.15	0.30	0.07	0.51	0.32	0.00	0.60	0.00
Resource Optimism	0.02	0.07	0.36	0.00	0.00	0.17	0.05	0.16	0.95	0.77	0.23	0.77	0.00	0.25	0.18	0.04	0.31	0.19	0.60	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 27: Co-occurrence Matrix for TestSmellDetector Tool

DISCUSSION - CO-OCCURRENCE OF TEST SMELLS BASED ON TESTSMELLDETECTOR TOOL

- Following co-occurence rates are low and reasons can be:
- For 'Magic Number Test' and 'Redundant Assertion':
  - The use of unclear literals doesn't necessarily lead to repeating assertions, and vice versa.
- For 'Magic Number Test' and 'Sleepy Test' :
  - The presence of arbitrary literal values ('Magic Number Test') in a test is unrelated to the use of unnecessary wait times

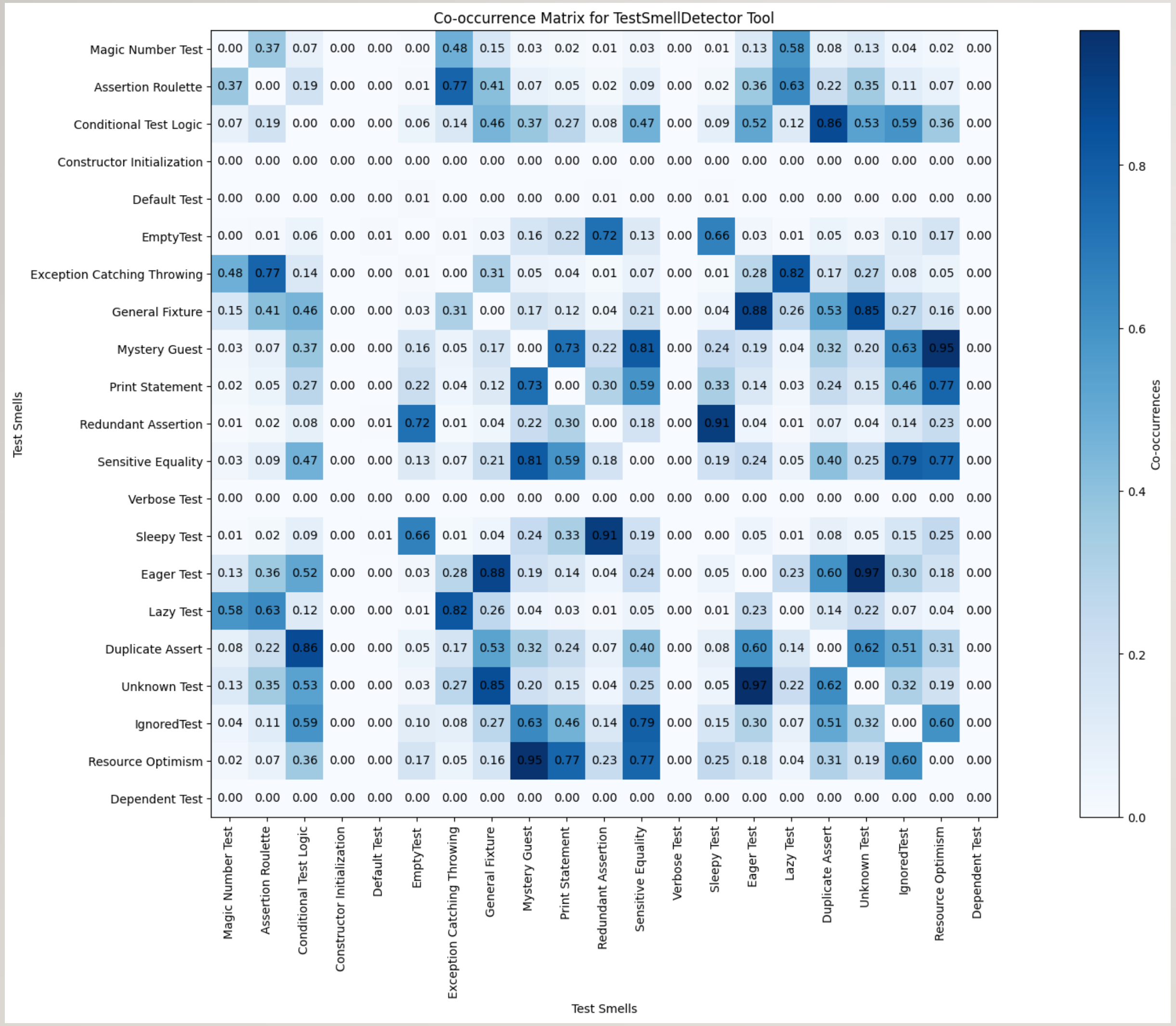


Test Smells	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.37	0.07	0.00	0.00	0.00	0.48	0.15	0.03	0.02	0.01	0.03	0.00	0.01	0.13	0.58	0.08	0.13	0.04	0.02	0.00
Assertion Roulette	0.37	0.00	0.19	0.00	0.00	0.01	0.77	0.41	0.07	0.05	0.02	0.09	0.00	0.02	0.36	0.63	0.22	0.35	0.11	0.07	0.00
Conditional Test Logic	0.07	0.19	0.00	0.00	0.00	0.06	0.14	0.46	0.37	0.27	0.08	0.47	0.00	0.09	0.52	0.12	0.86	0.53	0.59	0.36	0.00
Constructor Initialization	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.00	0.01	0.06	0.00	0.01	0.00	0.01	0.03	0.16	0.22	0.72	0.13	0.00	0.66	0.03	0.01	0.05	0.03	0.10	0.17	0.00
Exception Catching Throwing	0.48	0.77	0.14	0.00	0.00	0.01	0.00	0.31	0.05	0.04	0.01	0.07	0.00	0.01	0.28	0.82	0.17	0.27	0.08	0.05	0.00
General Fixture	0.15	0.41	0.46	0.00	0.00	0.03	0.31	0.00	0.17	0.12	0.04	0.21	0.00	0.04	0.88	0.26	0.53	0.85	0.27	0.16	0.00
Mystery Guest	0.03	0.07	0.37	0.00	0.00	0.16	0.05	0.17	0.00	0.73	0.22	0.81	0.00	0.24	0.19	0.04	0.32	0.20	0.63	0.95	0.00
Print Statement	0.02	0.05	0.27	0.00	0.00	0.22	0.04	0.12	0.73	0.00	0.30	0.59	0.00	0.33	0.14	0.03	0.24	0.15	0.46	0.77	0.00
Redundant Assertion	0.01	0.02	0.08	0.00	0.01	0.72	0.01	0.04	0.22	0.30	0.00	0.18	0.00	0.91	0.04	0.01	0.07	0.04	0.14	0.23	0.00
Sensitive Equality	0.03	0.09	0.47	0.00	0.00	0.13	0.07	0.21	0.81	0.59	0.18	0.00	0.00	0.19	0.24	0.05	0.40	0.25	0.79	0.77	0.00
Verbose Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sleepy Test	0.01	0.02	0.09	0.00	0.01	0.66	0.01	0.04	0.24	0.33	0.91	0.19	0.00	0.00	0.05	0.01	0.08	0.05	0.15	0.25	0.00
Eager Test	0.13	0.36	0.52	0.00	0.00	0.03	0.28	0.88	0.19	0.14	0.04	0.24	0.00	0.05	0.00	0.23	0.60	0.97	0.30	0.18	0.00
Lazy Test	0.58	0.63	0.12	0.00	0.00	0.01	0.82	0.26	0.04	0.03	0.01	0.05	0.00	0.01	0.23	0.00	0.14	0.22	0.07	0.04	0.00
Duplicate Assert	0.08	0.22	0.86	0.00	0.00	0.05	0.17	0.53	0.32	0.24	0.07	0.40	0.00	0.08	0.60	0.14	0.00	0.62	0.51	0.31	0.00
Unknown Test	0.13	0.35	0.53	0.00	0.00	0.03	0.27	0.85	0.20	0.15	0.04	0.25	0.00	0.05	0.97	0.22	0.62	0.00	0.32	0.19	0.00
IgnoredTest	0.04	0.11	0.59	0.00	0.00	0.10	0.08	0.27	0.63	0.46	0.14	0.79	0.00	0.15	0.30	0.07	0.51	0.32	0.00	0.60	0.00
Resource Optimism	0.02	0.07	0.36	0.00	0.00	0.17	0.05	0.16	0.95	0.77	0.23	0.77	0.00	0.25	0.18	0.04	0.31	0.19	0.60	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 28: Co-occurrence Matrix for TestSmellDetector Tool

DISCUSSION - CO-OCCURRENCE OF TEST SMELLS BASED ON TESTSMELLDETECTOR TOOL

- For 'Assertion Roulette' and 'Empty Test':
  - 'Assertion Roulette' involves tests with multiple unclear assertions, whereas an 'Empty Test' contains no executable statements or assertions at all
- For 'Empty Test' and 'Exception Catching Throwing':
  - Since 'Empty Test' lacks implementation, it cannot concurrently exhibit specific behaviors such as improperly managing exceptions ('Exception Catching Throwing').



	Magic Number Test	Assertion Roulette	Conditional Test Logic	Constructor Initialization	Default Test	EmptyTest	Exception Catching Throwing	General Fixture	Mystery Guest	Print Statement	Redundant Assertion	Sensitive Equality	Verbose Test	Sleepy Test	Eager Test	Lazy Test	Duplicate Assert	Unknown Test	IgnoredTest	Resource Optimism	Dependent Test
Magic Number Test	0.00	0.37	0.07	0.00	0.00	0.00	0.48	0.15	0.03	0.02	0.01	0.03	0.00	0.01	0.13	0.58	0.08	0.13	0.04	0.02	0.00
Assertion Roulette	0.37	0.00	0.19	0.00	0.00	0.01	0.77	0.41	0.07	0.05	0.02	0.09	0.00	0.02	0.36	0.63	0.22	0.35	0.11	0.07	0.00
Conditional Test Logic	0.07	0.19	0.00	0.00	0.00	0.06	0.14	0.46	0.37	0.27	0.08	0.47	0.00	0.09	0.52	0.12	0.86	0.53	0.59	0.36	0.00
Constructor Initialization	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Default Test	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EmptyTest	0.00	0.01	0.06	0.00	0.01	0.00	0.01	0.03	0.16	0.22	0.72	0.13	0.00	0.66	0.03	0.01	0.05	0.03	0.10	0.17	0.00
Exception Catching Throwing	0.48	0.77	0.14	0.00	0.00	0.01	0.00	0.31	0.05	0.04	0.01	0.07	0.00	0.01	0.28	0.82	0.17	0.27	0.08	0.05	0.00
General Fixture	0.15	0.41	0.46	0.00	0.00	0.03	0.31	0.00	0.17	0.12	0.04	0.21	0.00	0.04	0.88	0.26	0.53	0.85	0.27	0.16	0.00
Mystery Guest	0.03	0.07	0.37	0.00	0.00	0.16	0.05	0.17	0.00	0.73	0.22	0.81	0.00	0.24	0.19	0.04	0.32	0.20	0.63	0.95	0.00
Print Statement	0.02	0.05	0.27	0.00	0.00	0.22	0.04	0.12	0.73	0.00	0.30	0.59	0.00	0.33	0.14	0.03	0.24	0.15	0.46	0.77	0.00
Redundant Assertion	0.01	0.02	0.08	0.00	0.01	0.72	0.01	0.04	0.22	0.30	0.00	0.18	0.00	0.91	0.04	0.01	0.07	0.04	0.14	0.23	0.00
Sensitive Equality	0.03	0.09	0.47	0.00	0.00	0.13	0.07	0.21	0.81	0.59	0.18	0.00	0.00	0.19	0.24	0.05	0.40	0.25	0.79	0.77	0.00
Verbose Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sleepy Test	0.01	0.02	0.09	0.00	0.01	0.66	0.01	0.04	0.24	0.33	0.91	0.19	0.00	0.00	0.05	0.01	0.08	0.05	0.15	0.25	0.00
Eager Test	0.13	0.36	0.52	0.00	0.00	0.03	0.28	0.88	0.19	0.14	0.04	0.24	0.00	0.05	0.00	0.23	0.60	0.97	0.30	0.18	0.00
Lazy Test	0.58	0.63	0.12	0.00	0.00	0.01	0.82	0.26	0.04	0.03	0.01	0.05	0.00	0.01	0.23	0.00	0.14	0.22	0.07	0.04	0.00
Duplicate Assert	0.08	0.22	0.86	0.00	0.00	0.05	0.17	0.53	0.32	0.24	0.07	0.40	0.00	0.08	0.60	0.14	0.00	0.62	0.51	0.31	0.00
Unknown Test	0.13	0.35	0.53	0.00	0.00	0.03	0.27	0.85	0.20	0.15	0.04	0.25	0.00	0.05	0.97	0.22	0.62	0.00	0.32	0.19	0.00
IgnoredTest	0.04	0.11	0.59	0.00	0.00	0.10	0.08	0.27	0.63	0.46	0.14	0.79	0.00	0.15	0.30	0.07	0.51	0.32	0.00	0.60	0.00
Resource Optimism	0.02	0.07	0.36	0.00	0.00	0.17	0.05	0.16	0.95	0.77	0.23	0.77	0.00	0.25	0.18	0.04	0.31	0.19	0.60	0.00	0.00
Dependent Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 29: Co-occurrence Matrix for TestSmellDetector Tool

DISCUSSION - CO-OCCURRENCE OF TEST SMELLS BASED ON TESTSMELLDETECTOR TOOL

- For Empty Test' and 'Lazy Test':
  - 'Lazy Test' implies a test that inadequately verifies the functionality it's intended to test, often through overly simplistic or incomplete assertions. In contrast, an 'Empty Test' doesn't perform any action or assertion.

CONCLUSION

- With using 500 distinct open-source GitHub projects, These results are observed.
  - (i) the rate of detection of test smells by each tool,
    - With considering both tools' results, following 5 test smells are detected rarely: 'Dependent Test', 'Default Test', 'Sleepy Test', 'Redundant Assertion' and 'Constructor Initialization'.
    - With considering both tools' results, following 5 test smells are detected rarely: 'Dependent Test', 'Default Test', 'Sleepy Test', 'Redundant Assertion' and 'Constructor Initialization'.

CONCLUSION

- (ii) the number of affected test code files by test smells,
  - For JNose tool, test code files are affected by Magic Number Test and Lazy Test test smells mostly as 3056 and 1396 respectively.
  - For TestSmellDetector tool, test code files are affected by Magic Number Test and Assertion Roulette test smells frequently as 4222 and 2503 respectively.

CONCLUSION

- (iii) the co-occurrence rate of detected test smells with the mentioned tools.
  - Between 'Conditional Test Logic' and 'Eager Test' has most strong relationship with a co-occurrence value of [1.00] with using JNose tool.
  - Also, the pairing of 'Exception Catching Throwing' with 'Unknown Test' and a high co-occurrence rate of [0.99] of using JNose Tool shows a strong correlation.
  - On the other hand, the notable correlation observed in this case is between 'Unknown Test' and 'Eager Test' and their co-occurrence value of [0.97] with using TestSmellDetector tool.
  - Additionally, the pairing of 'Source Optimism' with 'Mystery Guest' has a strong co-occurrence rate of [0.95] with using TestSmellDetector Tool.

CONCLUSION – FUTURE WORK

- To study with larger projects, including a more extensive set of test smells.
- To implement a new tool to detect test smells and refactor them further.

SUGGESTIONS

- Any questions or suggestions ?