CPSC-60000-001 - Object Oriented Development

Group Assignment 1

Group: 7

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Contents

Section – 1

Empirical Study: Effect of Class Size on Software Maintainability

1.Introduction

In this empirical analysis, we look at the relation existing between class size and software maintainability. Our main aim is to study the effect of class size, expressed in lines of code (LoC), on multiple maintainability indices, including LCOM (Lack of Cohesion of Methods), DIT (Depth of Inheritance Tree), and CBO (Coupling Between Objects). Through scrutiny of real-world Java projects, we will provide relevant insights into the significant implications of class size on the overall quality of software.

1.1. Objectives:

- Examine the Relationship Between Class Size and Software Maintainability: Explore how different values of class size, measured as lines of code, impact important software metrics of maintainability.
- Assess Software Quality Using C&K Metrics: Implement the C&K metrics consisting of LCOM, DIT, and CBO to measure different options for software quality.
- Derive Insights from Real-world Java Projects: Empirical data, obtained from real Java projects, is used to generate meaningful patterns on class size and overall software maintainability that are based on the analysis of C&K metrics.

1.2 Questions:

- What impact does class size have on software maintainability?
- Which C&K metrics are most relevant for measuring maintainability?

1. 3 Metrics:

For this study, five metrics have been selected according to the Goal-Question-Metric (GQM) approach:

- LCOM (Lack of Cohesion in Methods): This metric measures how much class methods are scattered. It measures the interaction between methods in a class by counting the number of pairs of methods that do not share the same attributes.

- DIT (Depth of Inheritance Tree): DIT measures the node to the root of inheritance tree distance for the class. It exhibits the degree of domination or inclusiveness within the class formation.

- CBO (Coupling Between Objects): CBO counts the number of classes that a particular class connects to. It gives the specification of class communication and therefore, shows the level of connectivity for a software system.

- Complexity: This metric assesses the entirety of code complexity, which tells about its maintainability. It focuses on measures like cyclomatic complexity which translates to the number of linearly independent code paths to a given program, or maintainability index which gives a single quantitative value that describes the degree of maintenance that a program might need.

- Class Size (LoC): This measure of productivity determines the number of lines of code (LoC) per class size. It gives the attribute values of the individual classes regarding the length and complexity, that you can use as a metric for your maintenance.

These metrics are chosen to give an idea about the relationship between class size and the maintainability of software systems, with a focus on some aspects like cohesion, depth of inheritance, and class dependencies.

Section – 2

2.1. Criteria for Subject Programs with justification:

We want to Analyze the projects that are **over 5 years old** so that they go through many development and maintenance rounds. It should be more than **10,000 kB** to show its complexity and appropriateness for in-depth analysis, **over 10 contributors** to identify various perspectives of the project, and it should involve Java to picture real-world situations where developers work with different technologies. These criteria guarantee that the projects chosen for study are effective in the context of productivity and maintainability.

2.2. Subject Programs:

Project	Apache OpenNLP	MySQL Proxy using Java	Apache Atlas	Mirror of Apache	Simple Logging Facade for Java
Repository	https://github.com/apache/opennlp.git	https://github.com/MyCATApache/Mycat2	https://github.com/apache/atlas	https://github.com/apache/httpcomponents-client	https://github.com/qos-ch/slf4j
Module	opennlp-dl	Mycat2va	atlas\notification	httpclient5-fluent	slf4j-api
Language	Java	Java, MySQL	Java, Java Script	Java	Java
Size	14781 kbs	20013 kbs	63229 kbs	17523 kbs	11859 kbs
Start Time	April 25 2007	March 30 2015	September 16 2015	December 21 2005	March 6 2004
Contributors	50	11	132	88	78
Total lines of code	387	1262	2403	473	2221

2.3. What Programs do:

1. **Apache OpenNLP:** Apache OpenNLP is an open-source project for natural language processing using machine learning methods. It is deployed for the tasks performed in natural language processing like tokenization, sentence segmentation, part of speech identification, named entity identification, parsing, etc. It is one of the most used and powerful frameworks for NLP in Java.

2. **MySQL Proxy using Java:** Mycat2 is a MySQL Proxy that allows for shameless read/write splitting, database sharing, and high availability. It is a load balancer for the MySQL databases whose purpose is to handle client-server connections and efficiently pass SQL queries.

3. **Apache Atlas:** Apache Atlas is a framework for governance for Enterprise Hadoop. It is a governance and metadata management framework that supports the process of categorizing data assets, metadata, and data compliance within an organization. It helps in data identification, tracking of origin, and data categorization.

4. **Mirror of Apache HttpComponents Client:** The Apache HttpComponents Client Class is a Java HTTP client library that offers a variety of features designed to enhance performance. It supports the HTTP/1. 1 and HTTP/1. 0 It also supports with regards to connection management, request execution, and response handling. It is most commonly used to construct HTTP requests and communicate with web services.

5. **Simple Logging Facade for Java (SLF4J):** SLF4J is a simple abstraction for various logging frameworks such as Log Back, Log4J, and Commons Logging. This means that the end-user can select the type of logging that he wants to use at the time of deployment. SLF4J acts as an abstraction for logging mechanisms and provides ease and declarative implementation of logging in Java applications.

Section – 3

3.1. Tool Description:

The tool employed for this work is CodeMR a quality and static code analysis software that supports Java and C++ programming languages among others. CodeMR works in the Eclipse IDE environment and is a plugin for the Eclipse IDE. Its compatibility with Eclipse makes it a favored choice for programmers who are already using this IDE.

CodeMR provides a variety of functionalities for improving code quality, detecting potential problems, and proposing code transformations for improvement. Some of its key functionalities include:

- Static Code Analysis: CodeMR analyzes static Java/C++ codebases, providing both the detection of issues in the coding style, design, and potential vulnerabilities.
- Software Metrics: It gives metrics under different parameters of quality such as code readability, maintainability, and compliance with the code standards. This can be used to test the overall health of your code and spot potential issues.
- Dependency Analysis: CodeMR provides developers with additional features for dependency exploration and analysis to address dependency-related issues within their code.
- Code Visualization: CodeMR's visualization tools help developers view and manipulate their codebase graphically for a complex understanding of code structures and connections.
- Integration with Eclipse: CodeMR is a plugin in Eclipse that enables developers to perform code analysis and optimization within the Eclipse IDE.

To conclude, CodeMR is a useful and efficient application for performing software quality and static code analysis for Java and C++ programmers. Its support of Eclipse makes the integration of this tool as virtually seamless as it could be for developers familiar with this IDE.

3.2. Tool Citation:

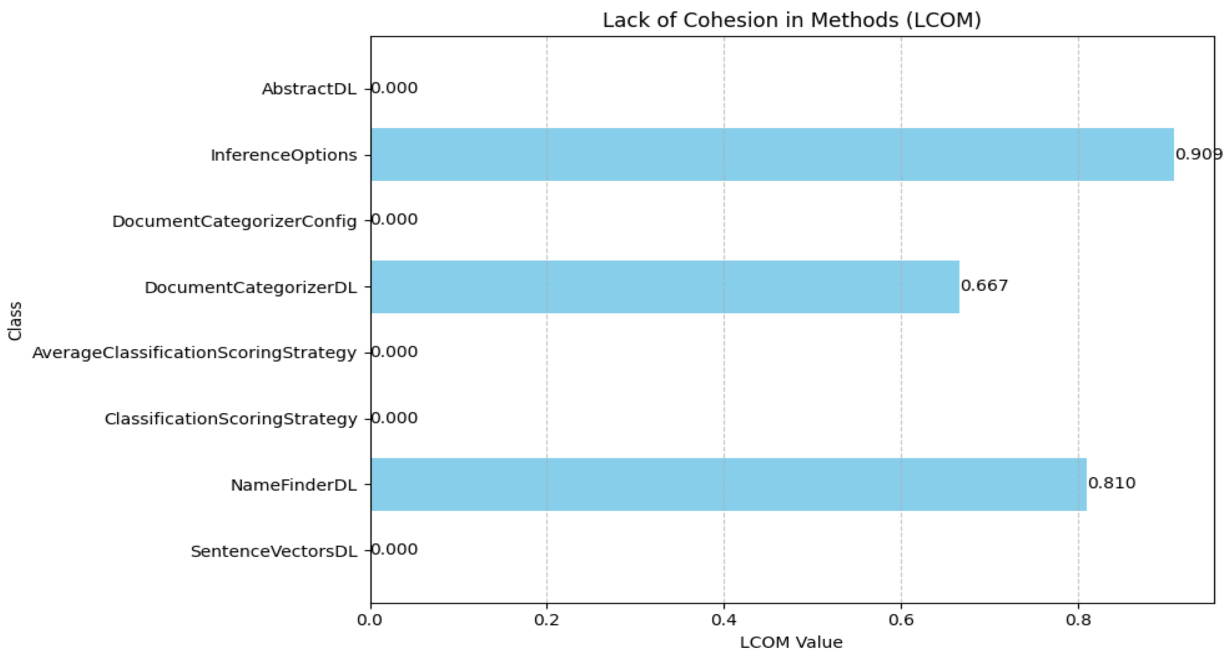
CodeMR. (n.d.). CodeMR - Multi-language Software Quality and Static Code Analysis Tool [Eclipse Marketplace listing]. Retrieved from https://marketplace.eclipse.org/content/codemr-static-code-analyser

Section – 4

4.1. Project: Apache OpenNLP
Module: opennlp-dl

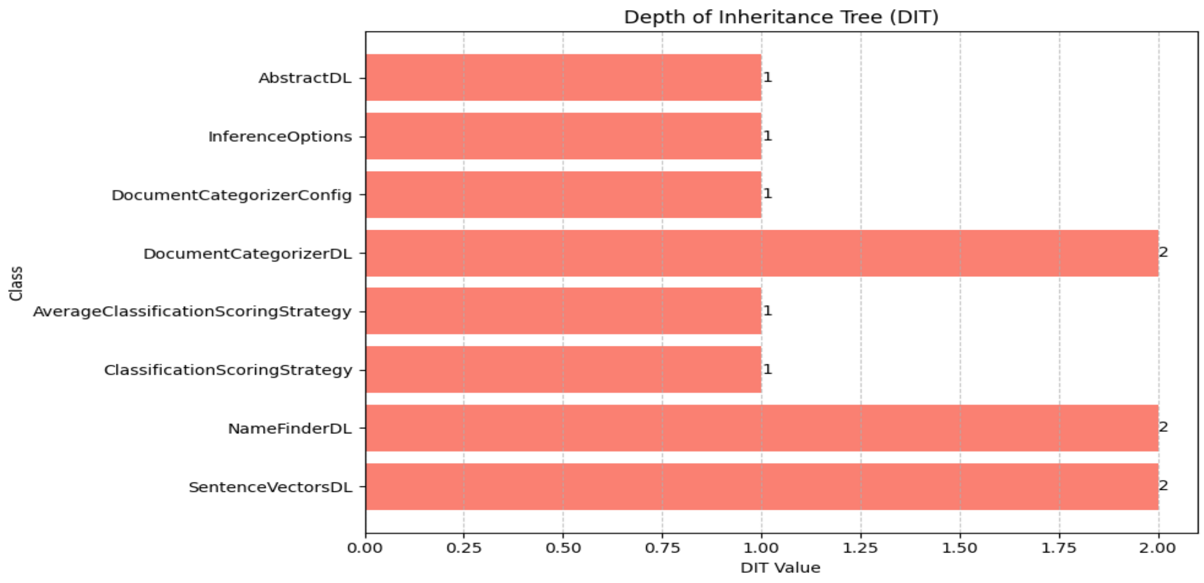
Class Element	LCOM	DIT	CBO	Complexity	Size	LOC
AbstractDL	0	1	3	low	low	14
InferenceOptions	0.909	1	0	low	low	31
DocumentCategorizerConfig	0	1	0	low	low	6
DocumentCategorizerDL	0.667	2	15	low-medium	low-medium	140
AverageClassificationScoringStrategy	0	1	0	low	low	12
ClassificationScoringStrategy	0	1	0	low	low	2
NameFinderDL	0.81	2	14	low-medium	low-medium	134
SentenceVectorsDL	0	2	9	low-medium	low	28

1. LCOM (Lack of Cohesion in Methods):



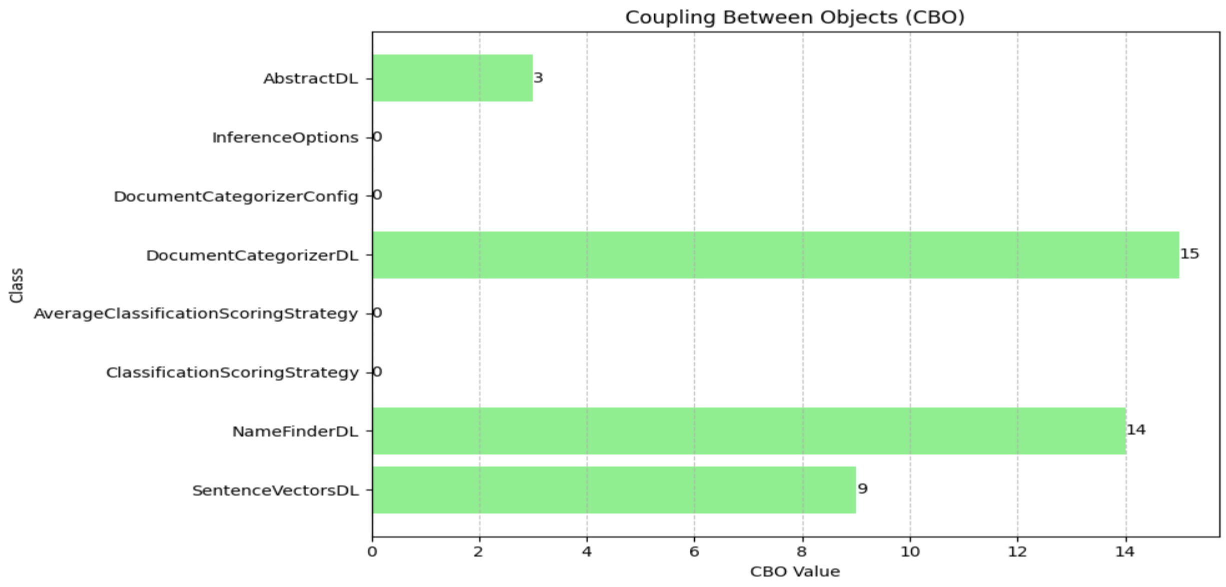
LCOM (Lack of Cohesion in Methods): Methods in most classes show a low lack of cohesion which is an indication of well-coupled methods in these classes. InferenceOptions and NameFinderDL have high values – this may imply that the methods within these classes are not cohesive.

2. DIT (Depth of Inheritance Tree):



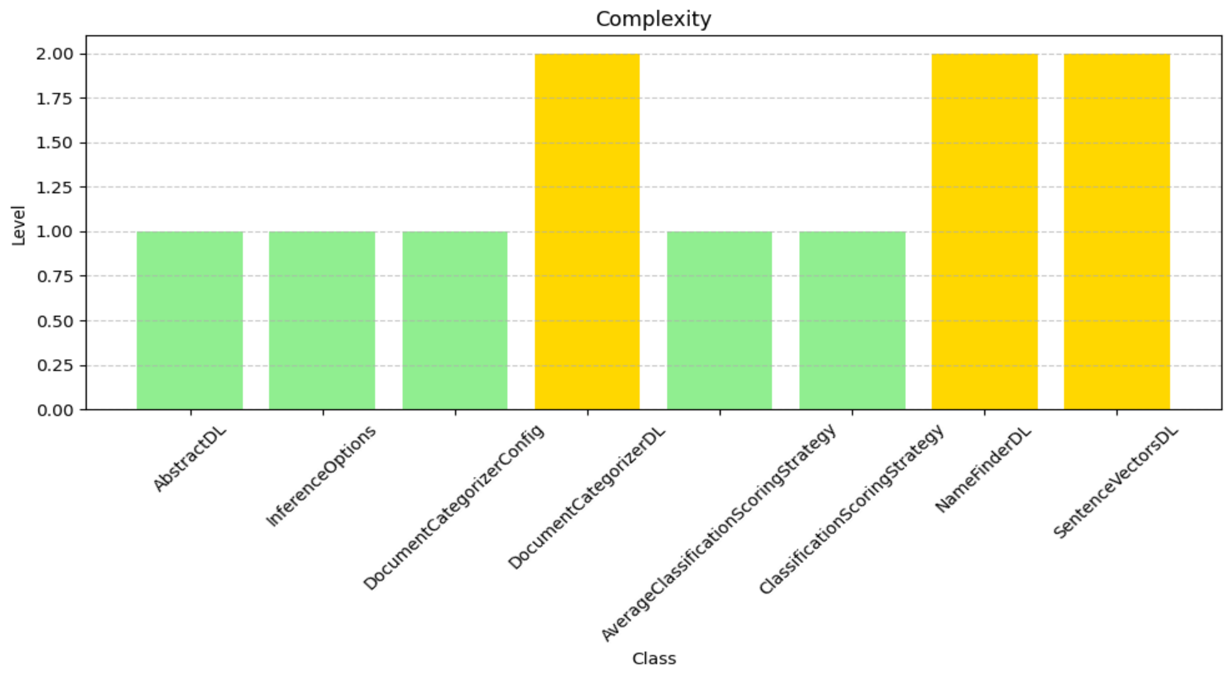
DIT (Depth of Inheritance Tree): Classes usually have an inheritance tree of 1 or 2 for example DocumentCategorizerDL, NameFinderDL, SentenceVectorsDL – has an inheritance depth of 2. All other classes have 1.

3. CBO (Coupling Between Objects):



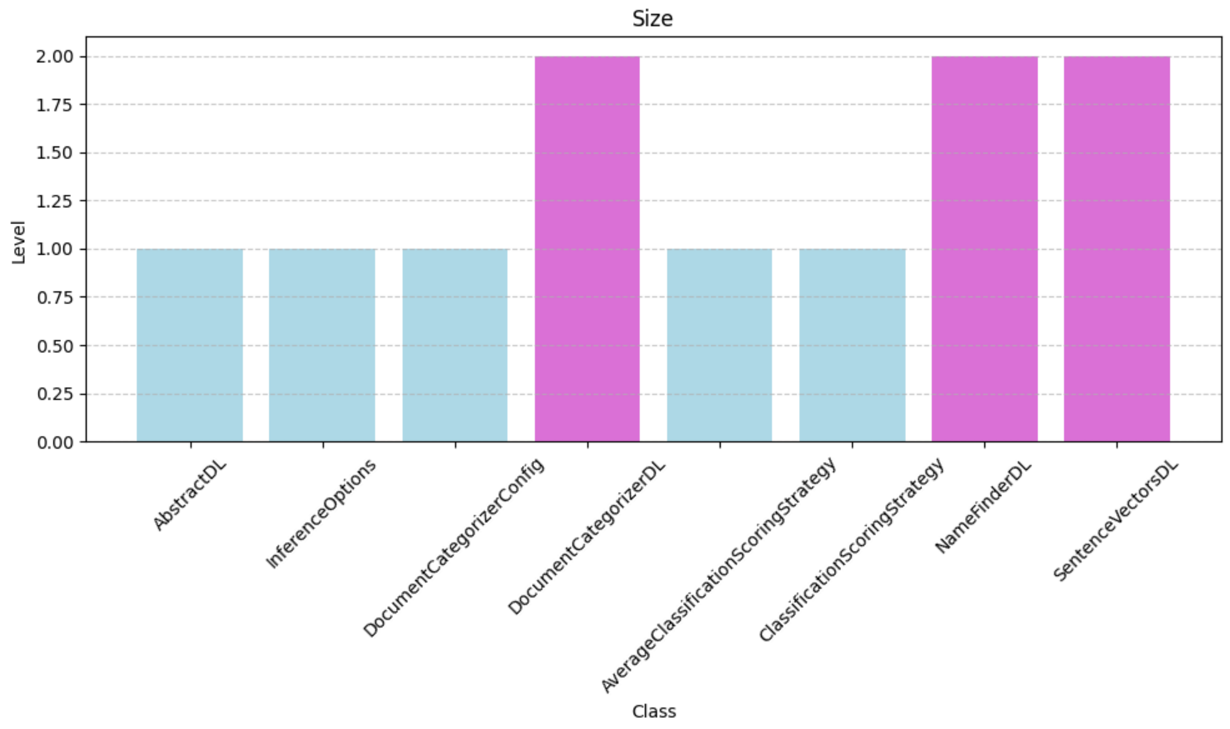
CBO (Coupling Between Objects): NameFinderDL and DocumentCategorizerDL classes are highly coupled with other classes than the rest, which might reflect a higher dependence between classes.

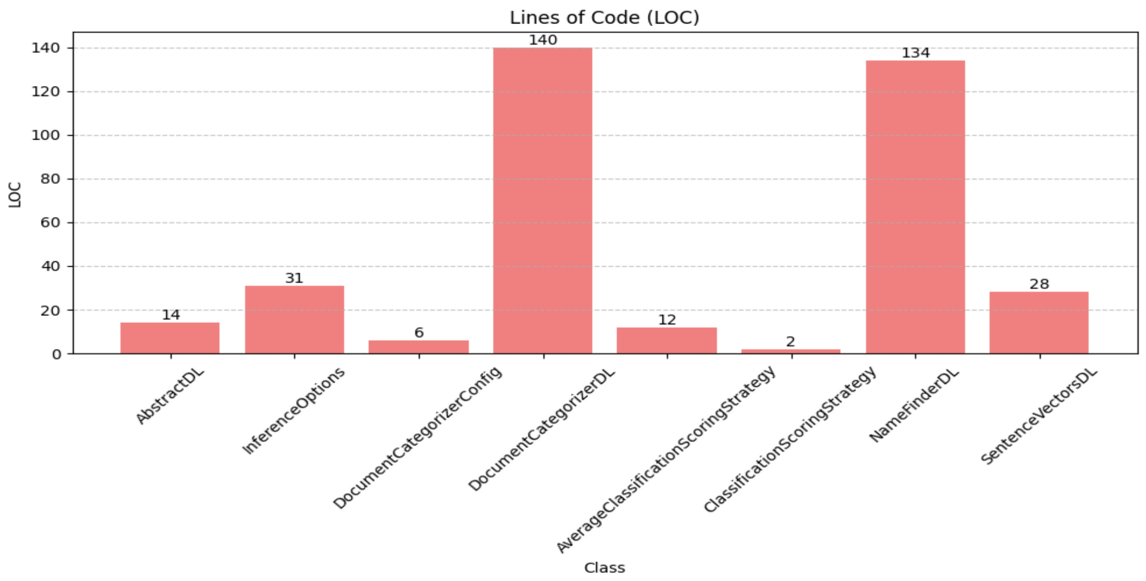
4. Complexity:



Complexity: The classes DocumentCategorizerDL, NameFinderDL, and SentenceVectorsDL score higher in terms of complexity, implying a greater level of complexity in the implementation of the logic underlying these classes.

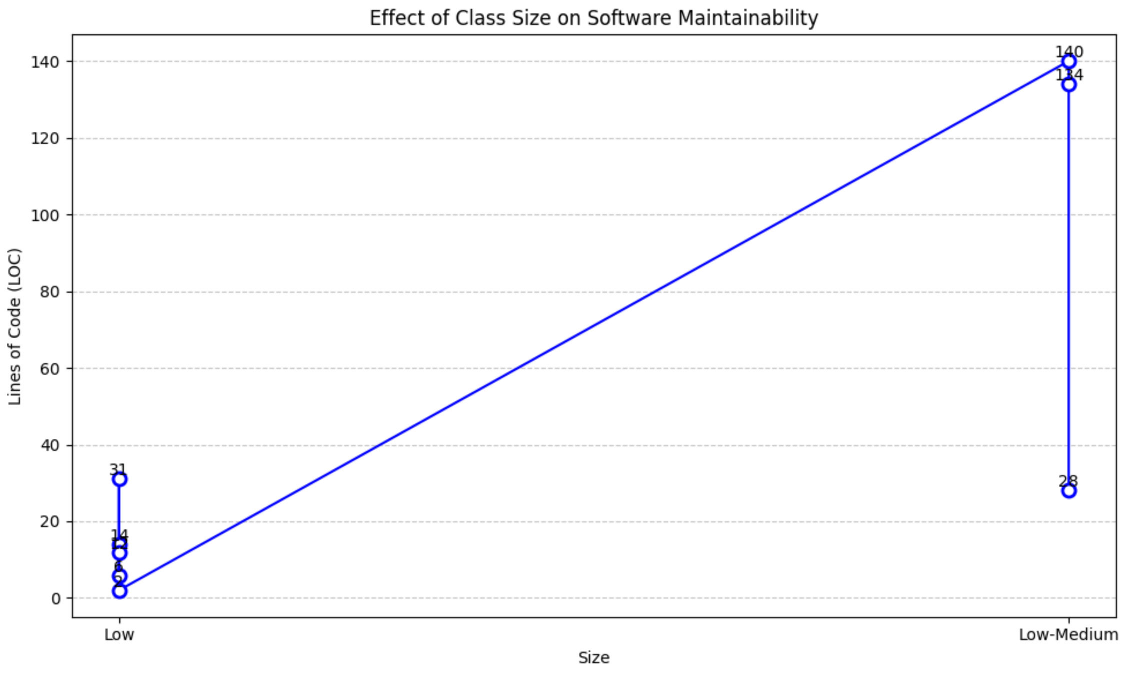
5. Size and LOC:





Size and LOC (Lines of Code): Out of all the classes, DocumentCategorizerDL has the highest size and LOC values meaning this class is taking more volume.

6. Effect of Class Size on Software Maintainability:

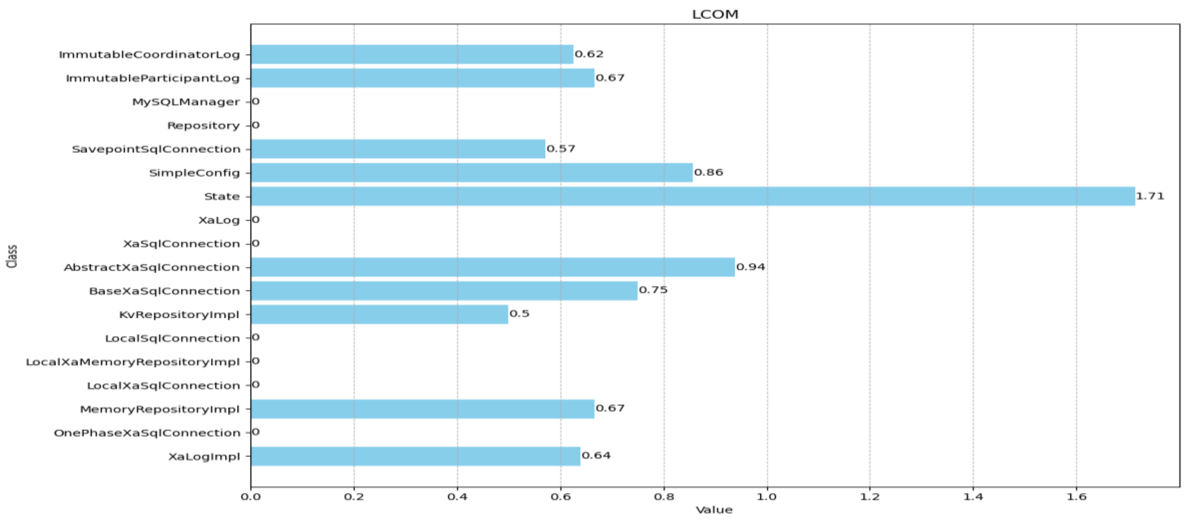


Higher LOC counts represent higher complexity and lower maintainability of aspects like DocumentCategorizerDL. There is a need to control the complexity of such classes for optimal software system maintainability and scalability requirements.

4.2. Project: MySQL Proxy using Java
Module: Mycat2va

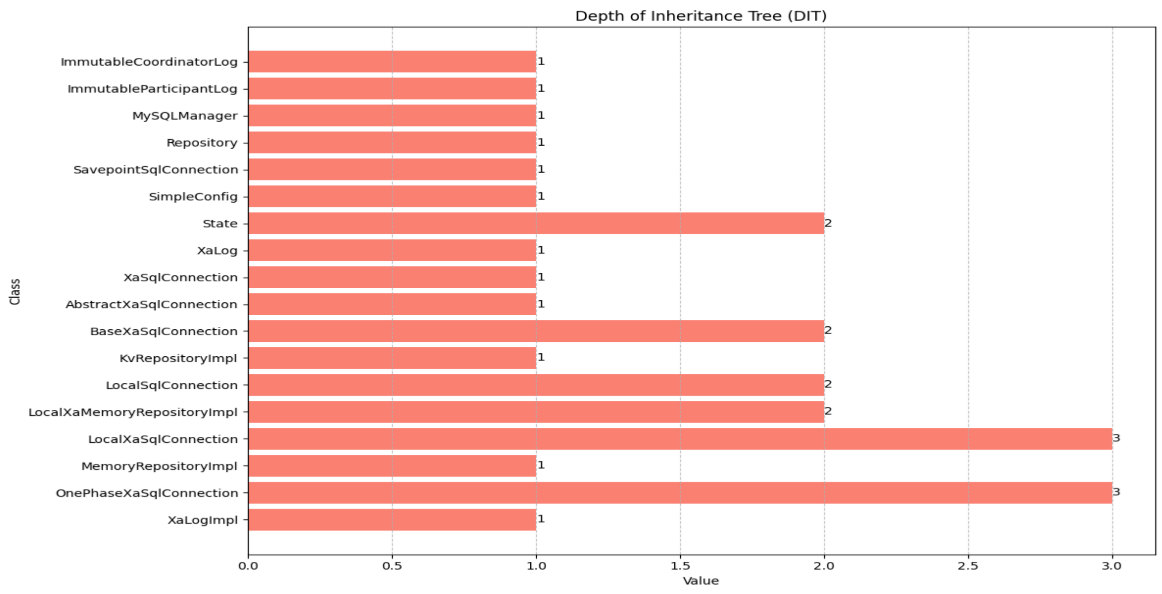
Class Element	LCOM	DIT	CBO	Complexity	Size	LOC
ImmutableCoordinatorLog	0.625	1	2	low	low-medium	74
ImmutableParticipantLog	0.667	1	1	low	low	19
MySQLManager	0	1	0	low	low	9
Repository	0	1	1	low	low	16
SavepointSqlConnection	0.571	1	0	low	low-medium	123
SimpleConfig	0.857	1	0	low	low	32
State	1.714	2	0	low-medium	low	13
XaLog	0	1	3	low	low	15
XaSqlConnection	0	1	0	low	low	34
AbstractXaSqlConnection	0.938	1	1	low	low	36
BaseXaSqlConnection	0.75	2	4	low-medium	medium-high	314
KvRepositoryImpl	0.5	1	1	low	low	25
LocalSqlConnection	0	2	1	low-medium	low-medium	120
LocalXaMemoryRepositoryImpl	0	2	0	low-medium	low	28
LocalXaSqlConnection	0	3	0	low-medium	low-medium	171
MemoryRepositoryImpl	0.667	1	2	low	low-medium	54
OnePhaseXaSqlConnection	0	3	0	low-medium	low	24
XaLogImpl	0.639	1	6	low-medium	low-medium	155

1. LCOM (Lack of Cohesion in Methods):



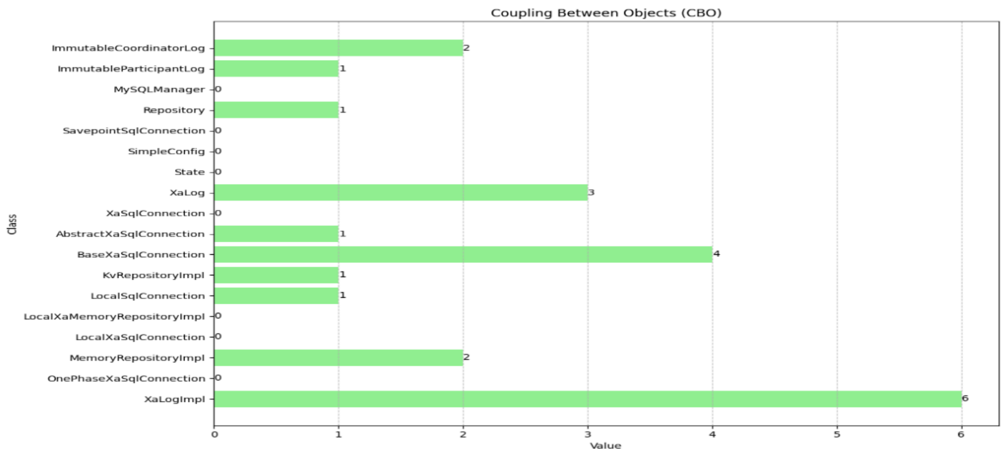
LCOM (Lack of Cohesion in Methods): Most classes display a low lack of cohesion between methods, which suggests that methods in these classes are cohesive. However, the State class is exceptionally high, which means that this reveals the possibility of a high level of lack of cohesion in methods within this class.

2. DIT (Depth of Inheritance Tree):



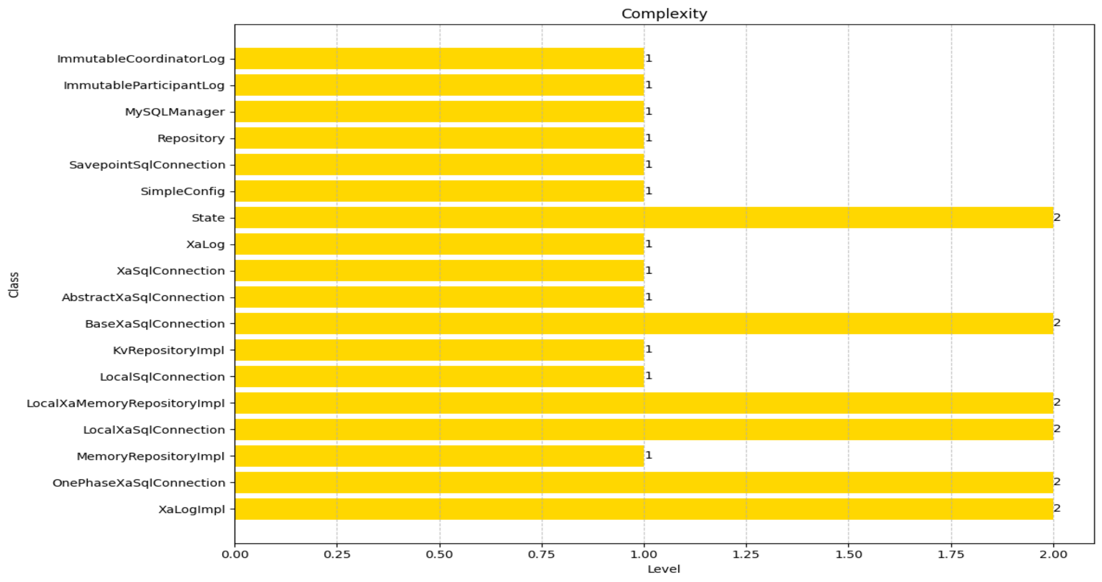
DIT (Depth of Inheritance Tree): The DIT in classes is usually 1 though there are some specific classes like the State and BaseXaSqlConnection having a DIT of 2 and the LocalXaSqlConnection having a DIT of 3. These exceptions suggest a bit larger hierarchy in these classes.

3. CBO (Coupling Between Objects):



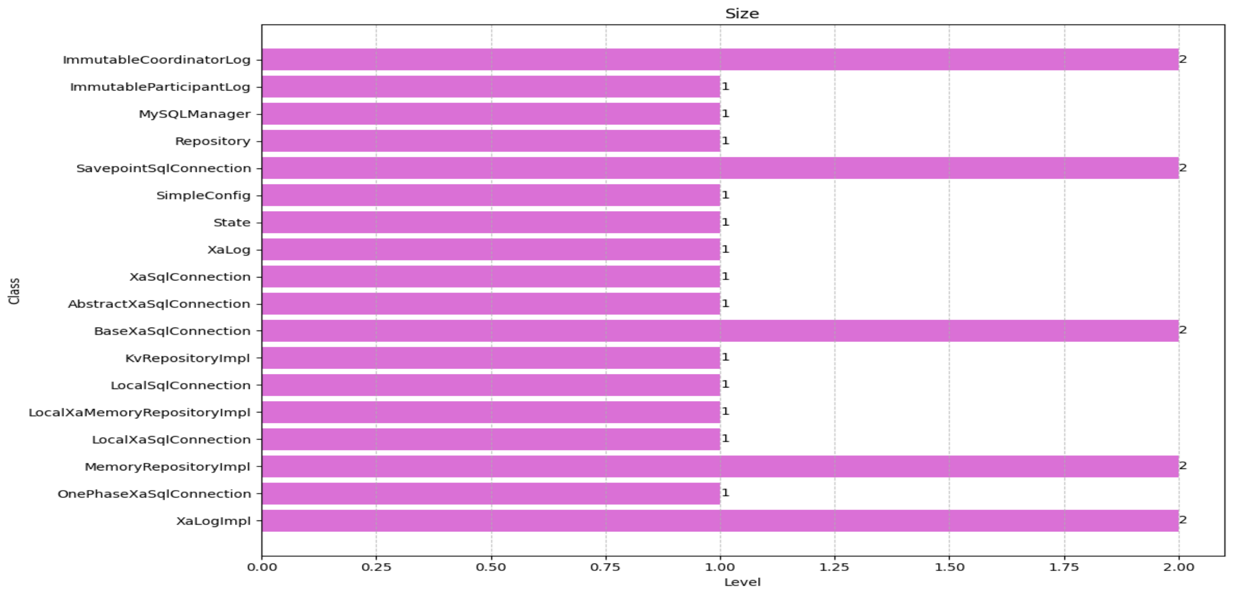
CBO (Coupling Between Objects): BaseXaSqlConnection and XaLogImpl have the highest object coupling among the classes involved in the provided inquiry and therefore higher dependency.

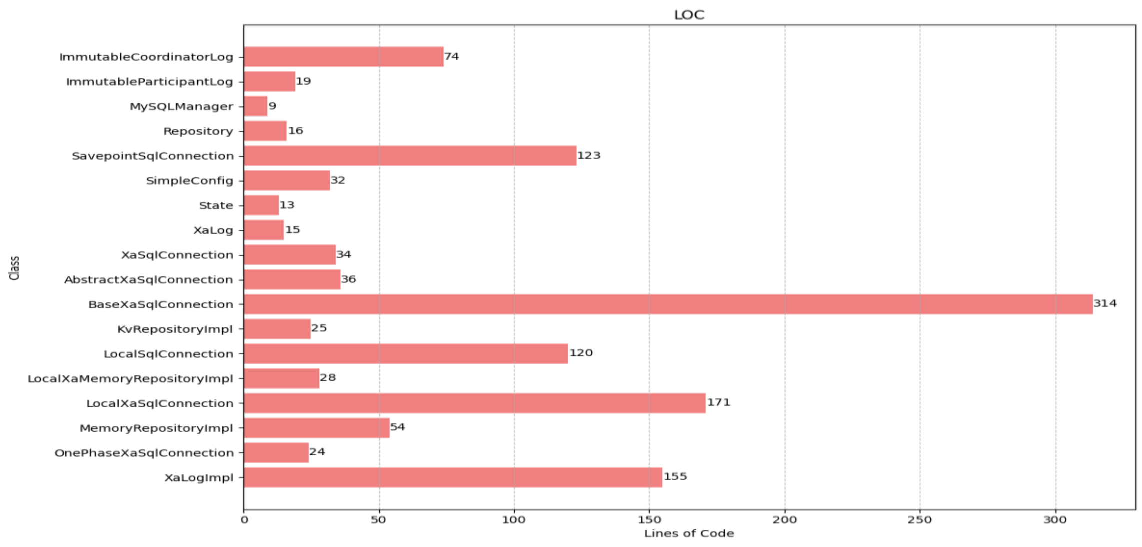
4. Complexity:



Complexity: The complexity of the State, BaseXaSqlConnection, and XaLogImpl classes is slightly higher than the complexity of the classes they are compared to.

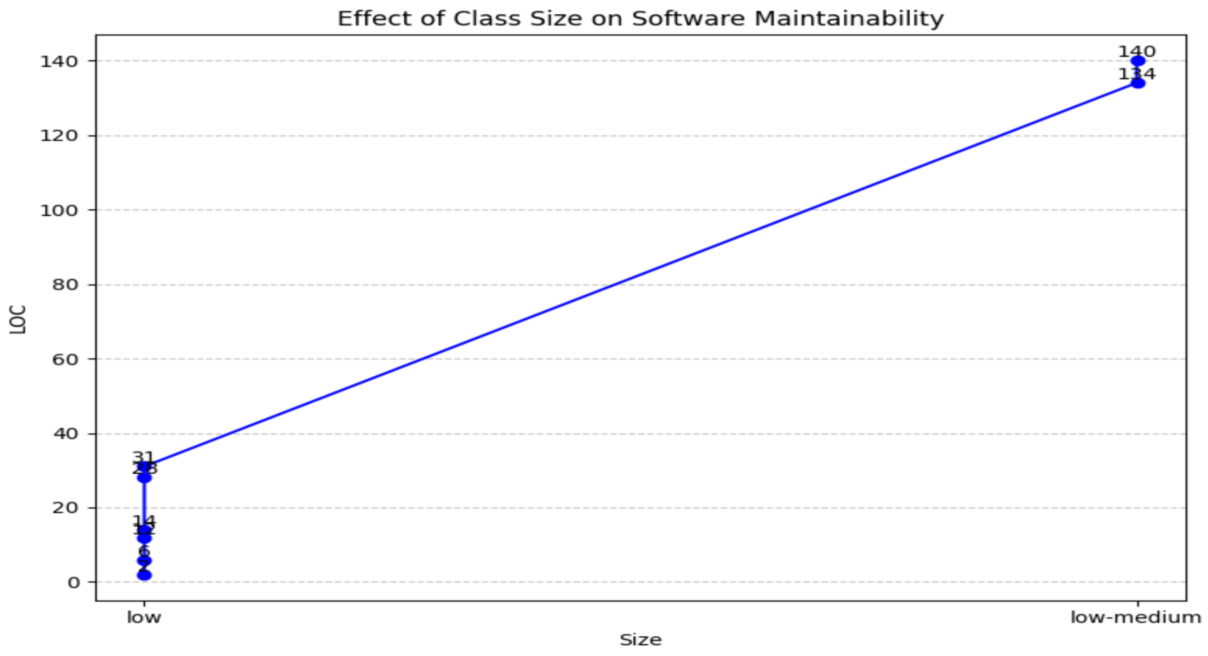
5. Size and LOC:





Size and LOC (Lines of Code): BaseXaSqlConnection is the largest and has the highest size and LOC values, which means it is the biggest class with the most complex code.

6. Effect of Class Size on Software Maintainability:

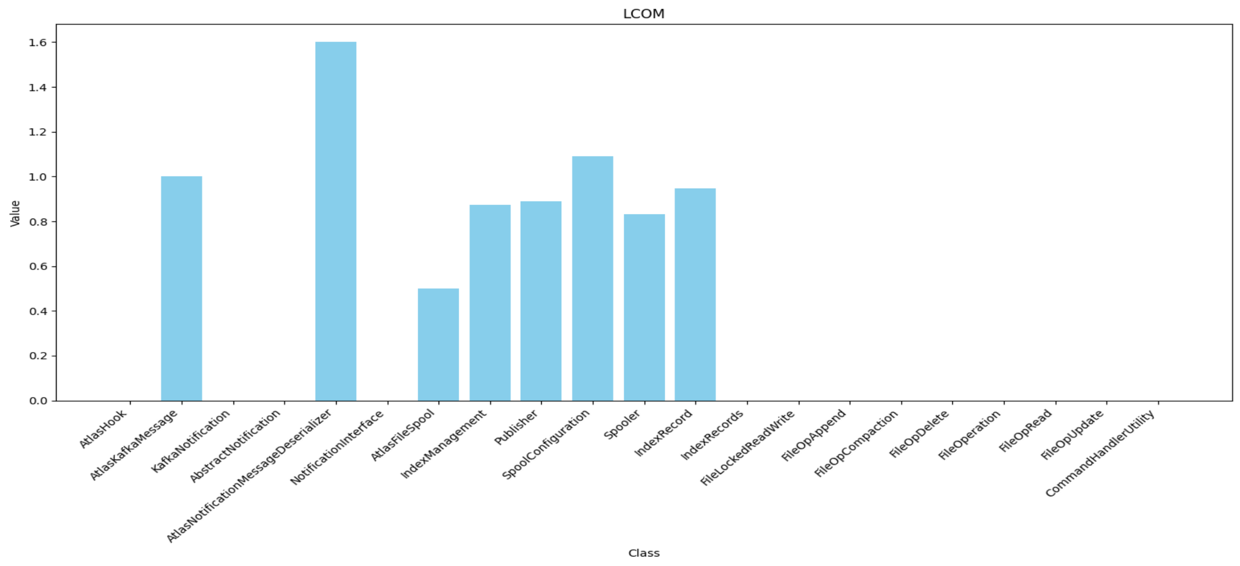


The LOC of classes with larger sizes, for example, BaseXaSqlConnection and LocalXaSqlConnection are larger which indicates a larger number of development activities and lower maintainability of such classes. This observation shows how necessary it is to control the complexity of such classes to achieve the maintainability and scalability of software.

4.3. Project: Apache Atlas
Module: atlas\notification

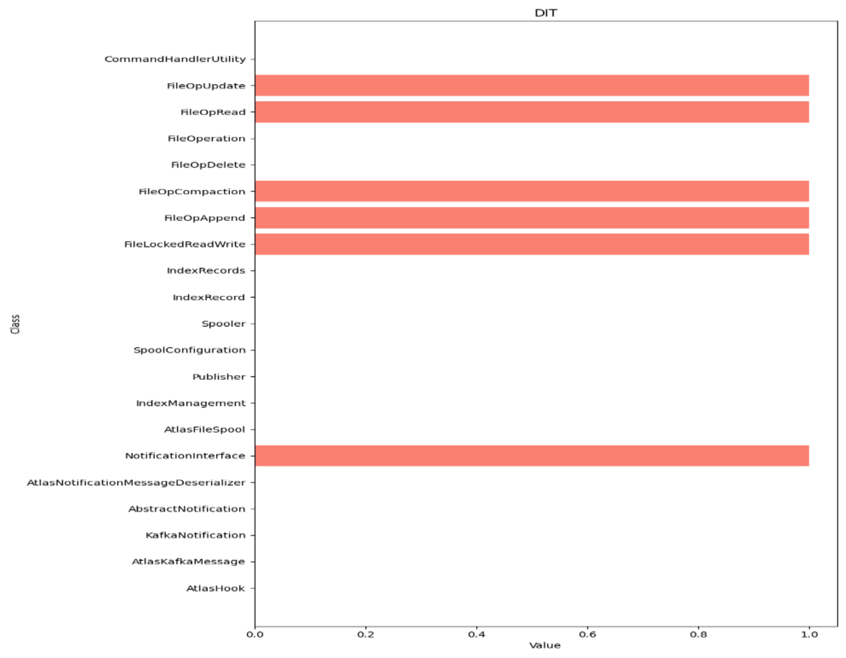
Class Element	LCOM	DIT	CBO	Complexity	Size	LOC
AtlasHook	0	0	1	low	low-medium	157
AtlasKafkaMessage	1	0	1	low	low	38
KafkaNotification	0	0	0	low	low-medium	240
AbstractNotification	0	0	1	low	low-medium	87
AtlasNotificationMessageDeserializer	1.6	0	0	low	low-medium	166
NotificationInterface	0	1	0	low	low	19
AtlasFileSpool	0.5	0	4	low	low-medium	97
IndexManagement	0.875	0	1	low	low-medium	266
Publisher	0.889	0	2	low	low-medium	119
SpoolConfiguration	1.091	0	0	low	low-medium	86
Spooler	0.833	0	2	low	low-medium	63
IndexRecord	0.948	0	0	low-medium	low-medium	119
IndexRecords	0	0	1	low	low	32
FileLockedReadWrite	0	1	0	low	low	25
FileOpAppend	0	1	0	low	low	9
FileOpCompaction	0	1	1	low	low	16
FileOpDelete	0	1	0	low	low	14
FileOperation	0	0	0	low	low-medium	84
FileOpRead	0	1	0	low	low	20
FileOpUpdate	0	1	1	low	low	21
CommandHandlerUtility	0	0	0	low	low	39

1. **LCOM (Lack of Cohesion in Methods):**



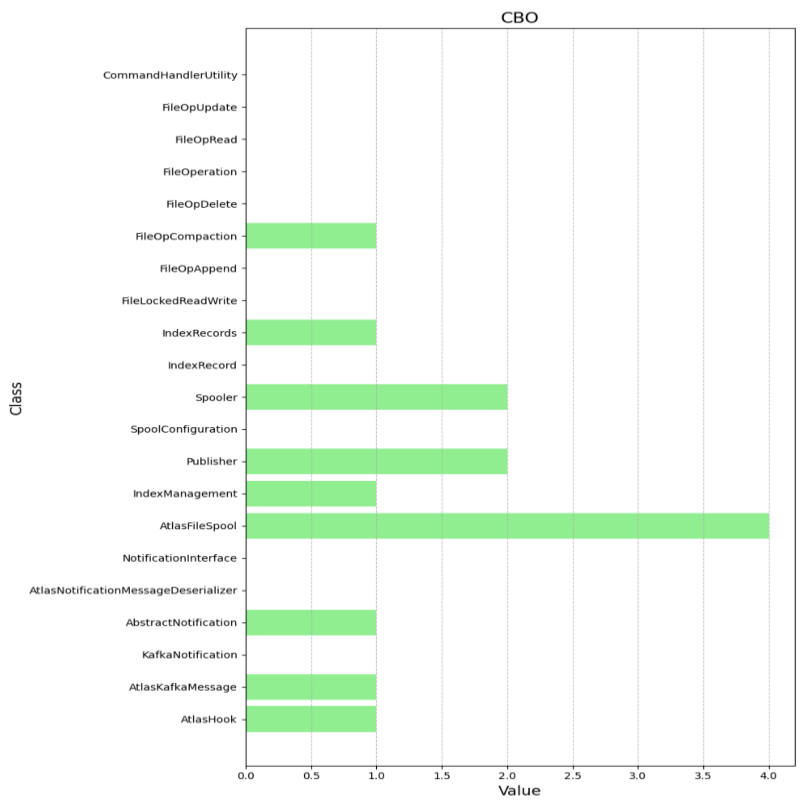
LCOM (Lack of Cohesion in Methods): The majority of classes were reported to have low lack of cohesion in methods, AtlasNotificationMessageDeserializer being the one to have the highest LCOM which signifies low cohesion in methods for this class.

2. DIT (Depth of Inheritance Tree):



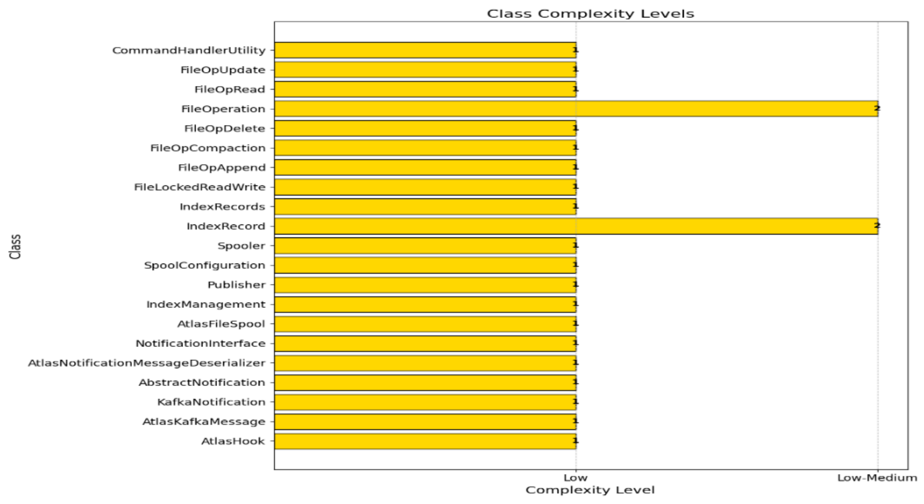
DIT (Depth of Inheritance Tree): Classes have a DIT of 0 meaning that there is no inheritance and others have a DIT of 1.

3. CBO (Coupling Between Objects):



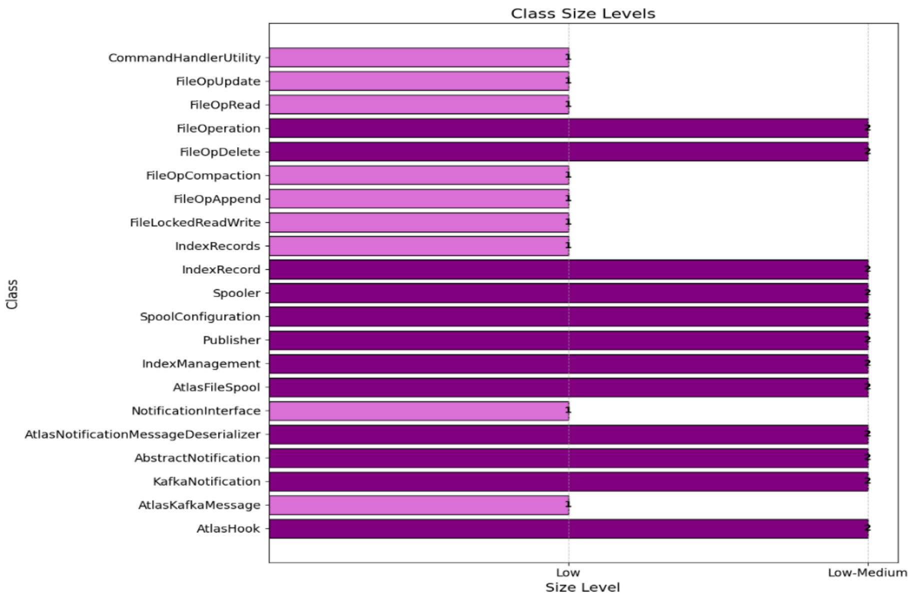
CBO (Coupling Between Objects): AtlasFileSpool has the highest coupling with a CBO value of 4 interfaces to Publisher and Spooler with a CBO value of 2.

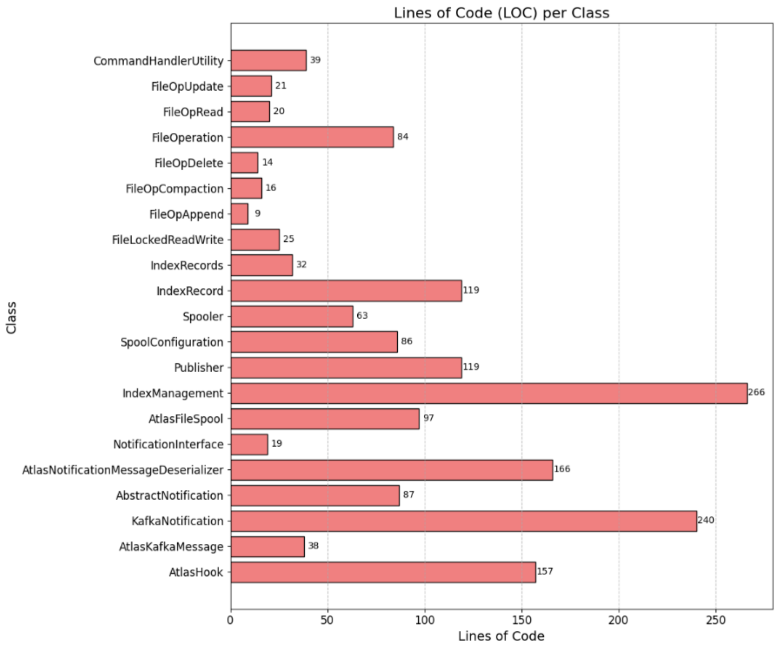
4. Complexity:



Complexity: Among the classes under consideration, AtlasHook, KafkaNotification, and CommandHandlerUtility have low complexity while IndexRecord shows a slightly high complexity compared with other classes.

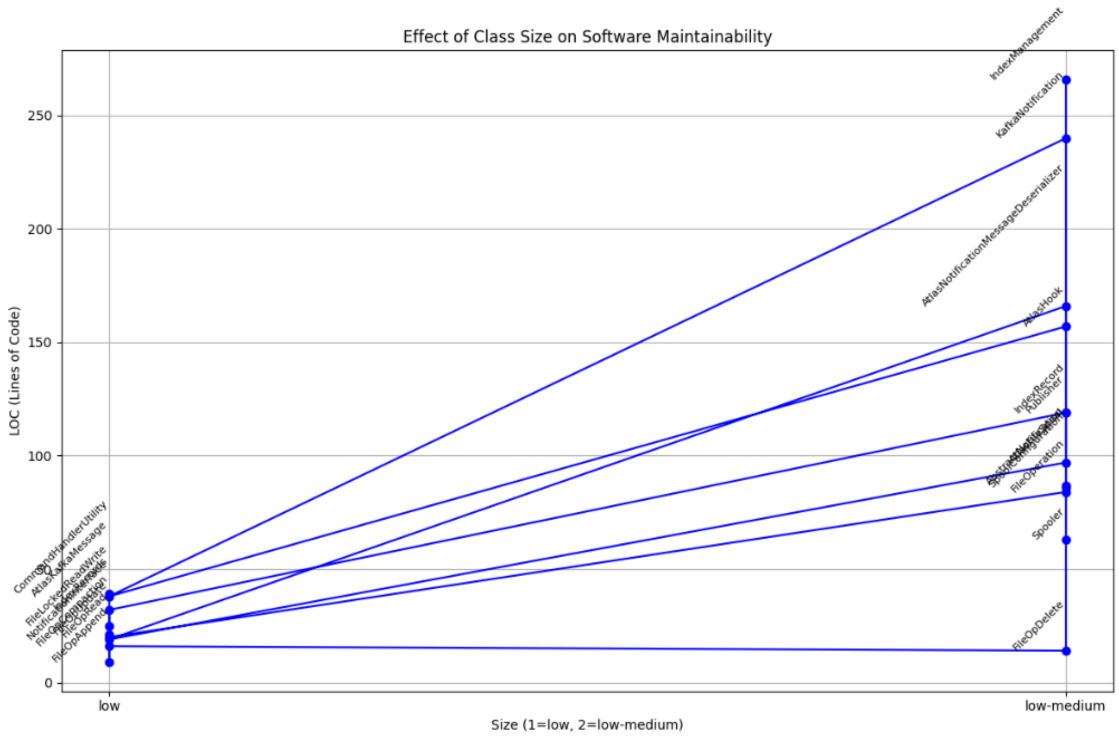
5. Size and LOC:





Size and LOC (Lines of Code): KafkaNotification is the largest class in terms of LOC, with AtlasNotificationMessageDeserializer and IndexManagement following closely behind.

6. Effect of Class Size on Software Maintainability:

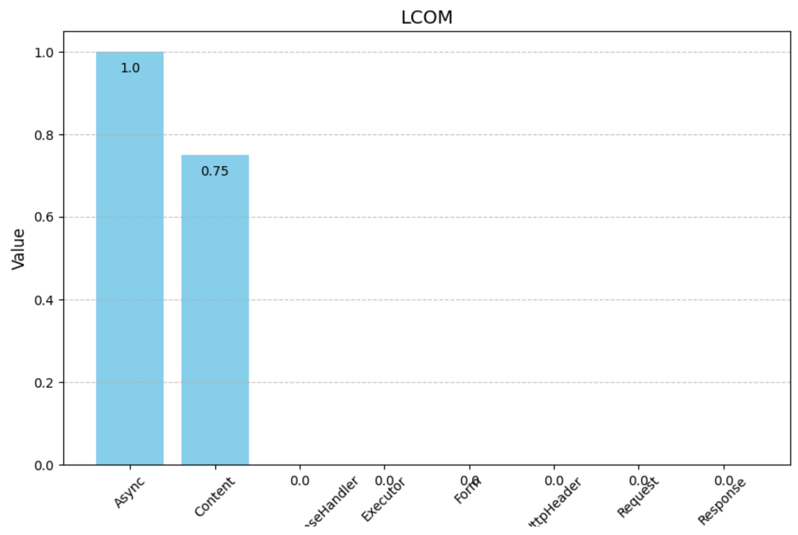


Classes with larger sizes, such as KafkaNotification, AtlasNotificationMessageDeserializer, and IndexManagement, tend to have higher LOC values, indicating potentially higher complexity and lower maintainability. This observation emphasizes the need to manage the complexity of such classes to ensure maintainability and scalability of the software system.

4.4. Project: Mirror of Apache Module: httpclient5-fluent

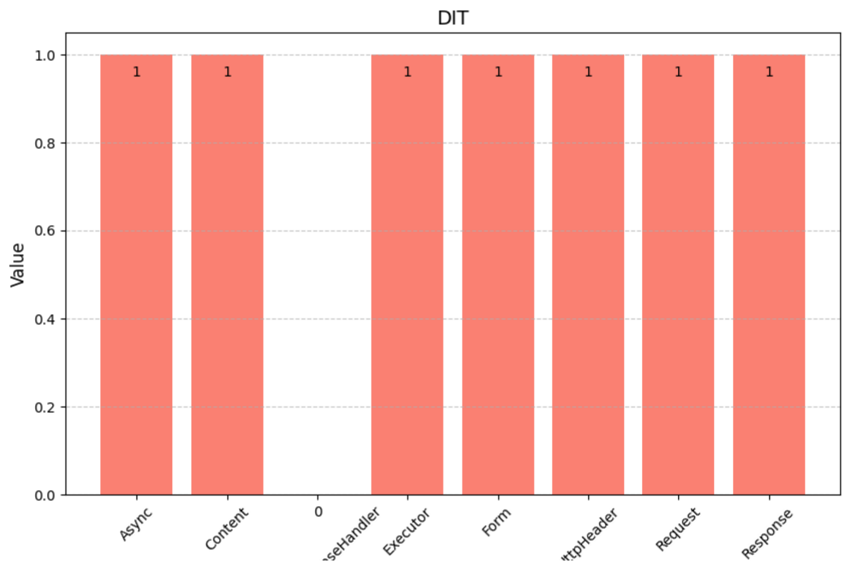
Class Element	LCOM	DIT	CBO	Complexity	Size	LOC
Async	1	1	3	low	low-medium	57
Content	0.75	1	0	low	low	24
ContentResponseHandler	0	0	0	low	low	15
Executor	0	1	2	low	low-medium	112
Form	0	1	0	low	low	12
HttpHeader	0	1	0	low	low	7
Request	0	1	2	low-medium	low-medium	184
Response	0	1	2	low	low-medium	62

1. **LCOM (Lack of Cohesion in Methods):**



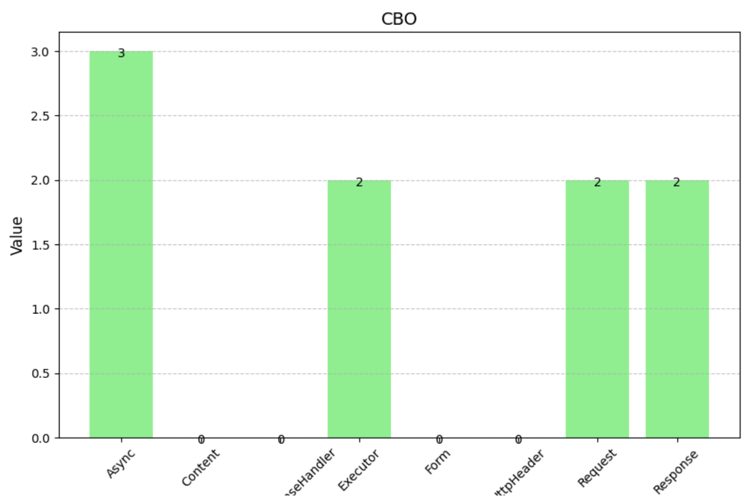
LCOM (Lack of Cohesion in Methods): All the classes have a medium-low lack of cohesion in methods hence associated with relatively cohesive methods in the classes. The Async class has an LCOM value of 1 that implies flawed cohesion for methods in the class. LCOM for classes Content and ContentResponseHandler are still low but relatively higher than the others.

2. **DIT (Depth of Inheritance Tree):**



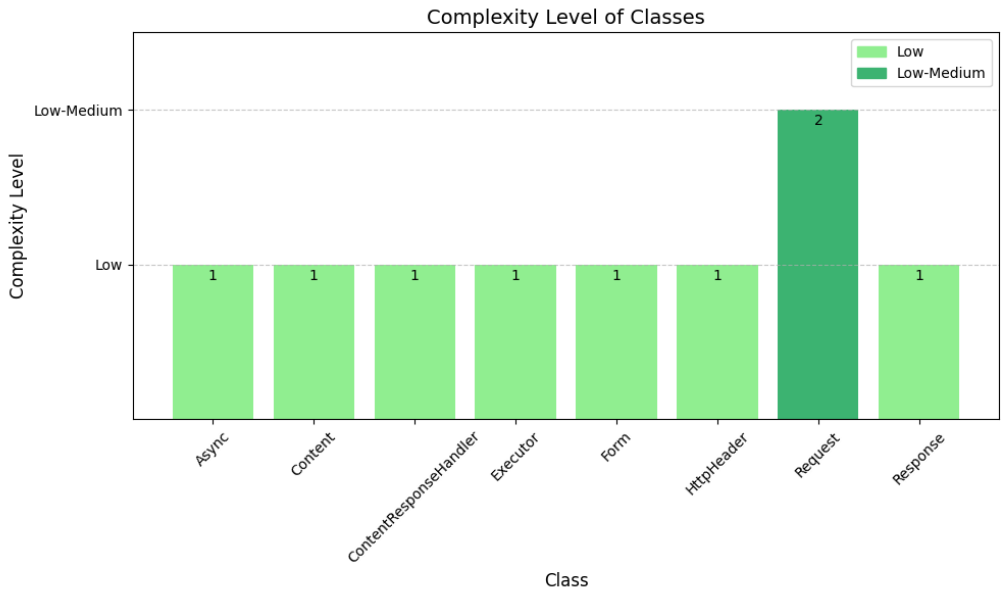
DIT (Depth of Inheritance Tree): Inheritance trees are usually flat with DIT 1 for most classes. Async, Content, Executor, Form, HttpHeader, Request, and Response classes each have a DIT of 1. No class shows a major inheritance hierarchy.

3. CBO (Coupling Between Objects):



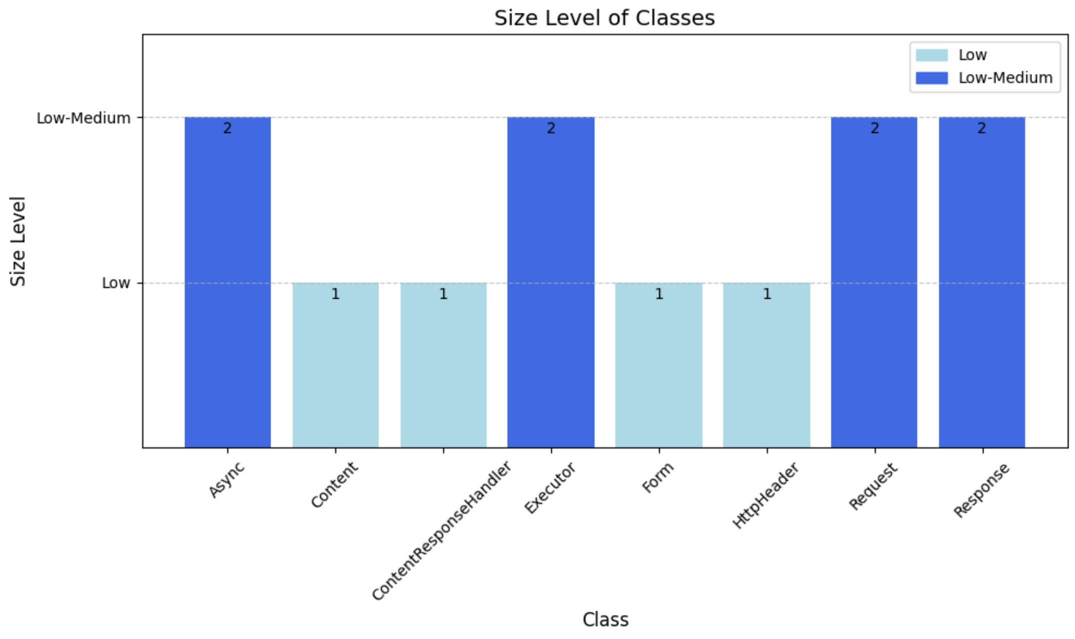
CBO (Coupling Between Objects): The Async, Executor, and Request and Response classes have more tightly coupled objects than the rest because they have CBOs of 3 or 2. Classes like: Content, ContentResponseHandler, Form, and HttpHeader have low coupling in the CBO having a value of 0.

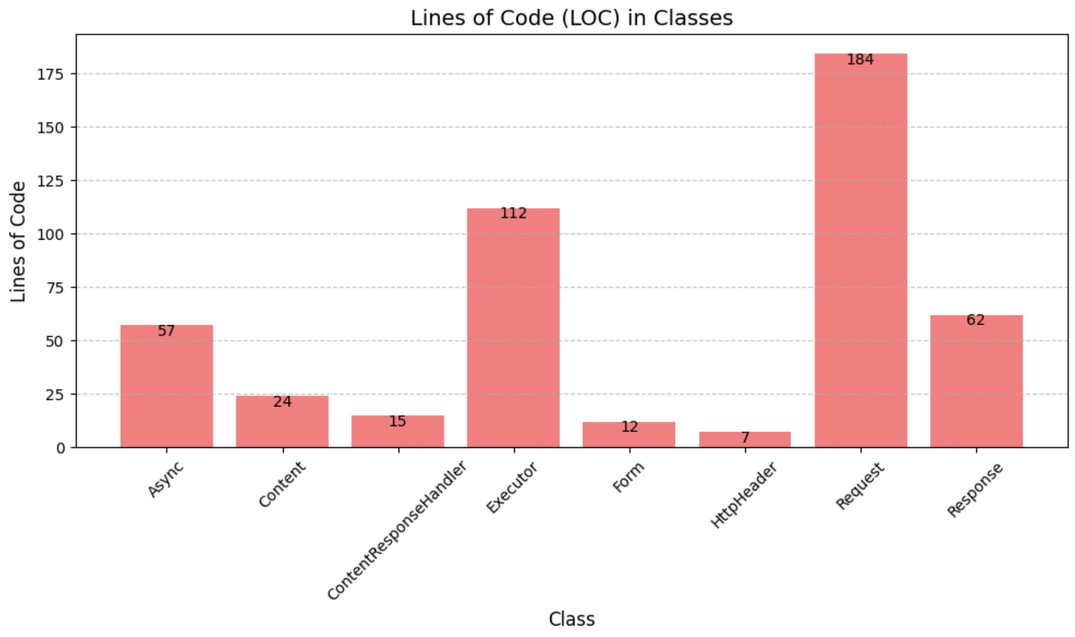
4. Complexity:



Complexity: The majority of classes are simple in terms of size and design. The complexity of the Async, Executor, Request, as well as Response classes' performance, is not high but slightly less than on the weak level. Content class, ContentResponseHandler class, Form class, and HttpHeader class have a low level of complexity.

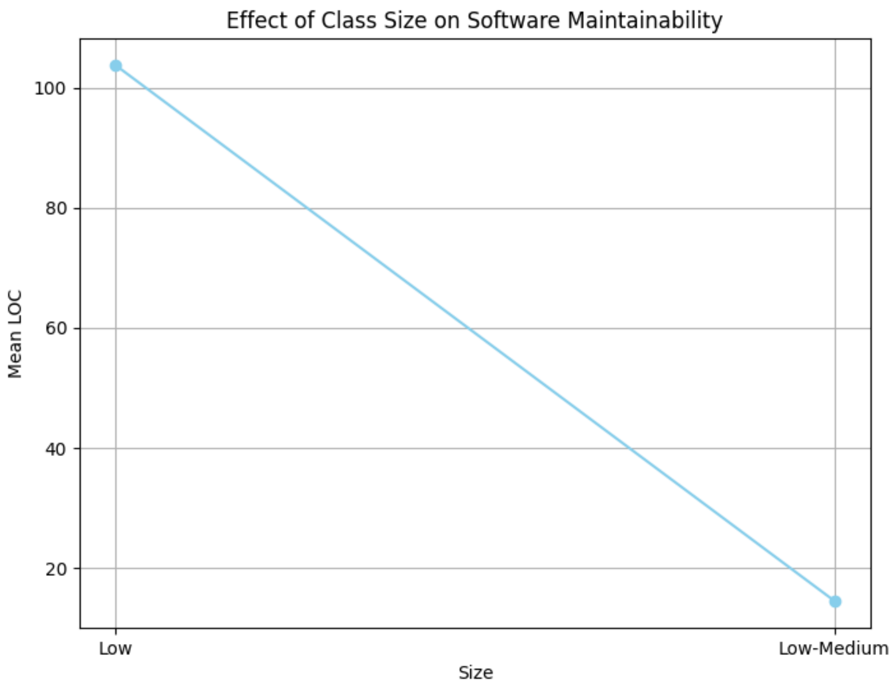
5. Size and LOC:





Size and LOC (Lines of Code): The classes in the application range from smallest to largest in terms of number of lines of code: Request: 184 LOC; Executor: 112 LOC. HttpHeader and ContentResponseHandler are the least complex classes with 7 and 15 knots respectively. Async, Content, LOC, Form, and Response classes have relatively low LOC values.

6. Effect of Class Size on Software Maintainability:



Larger classes such as Request and Executor tend to have higher LOC values, indicating potentially higher complexity and lower maintainability.

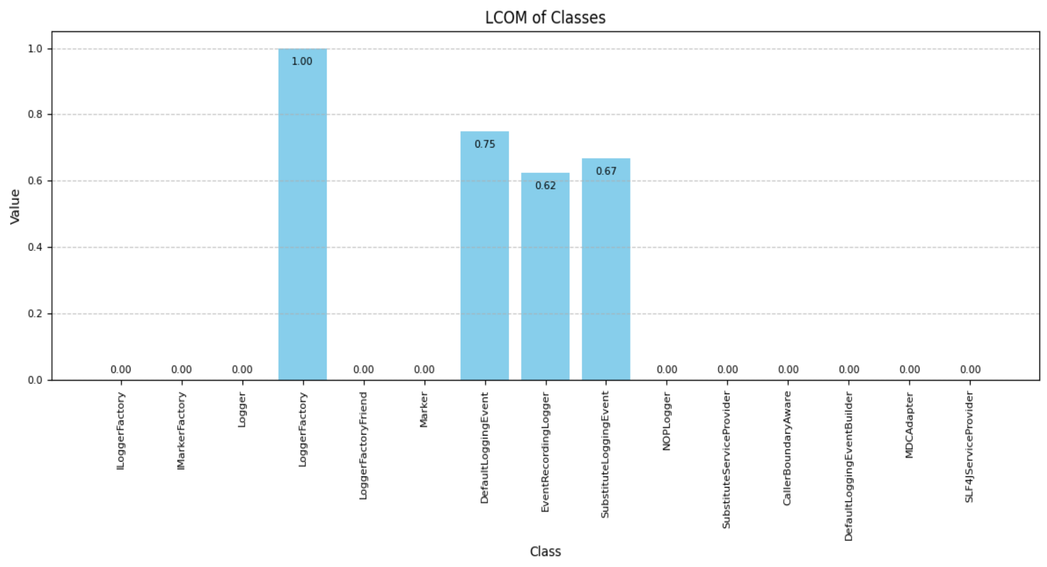
Smaller classes like HttpHeader and ContentResponseHandler show lower LOC values, suggesting simpler and potentially more maintainable code.

4.5. Project: Simple Logging Facade for Java
Module: slf4j-api

Class Element	LCOM	DIT	CBO	Complexity	Size	LOC
ILoggerFactory	0	1	0	low	low	2
IMarkerFactory	0	1	0	low	low	5
Logger	0	1	1	low	low-medium	116
LoggerFactory	1	0	2	low-medium	low-medium	235
LoggerFactoryFriend	0	0	1	low	low	5

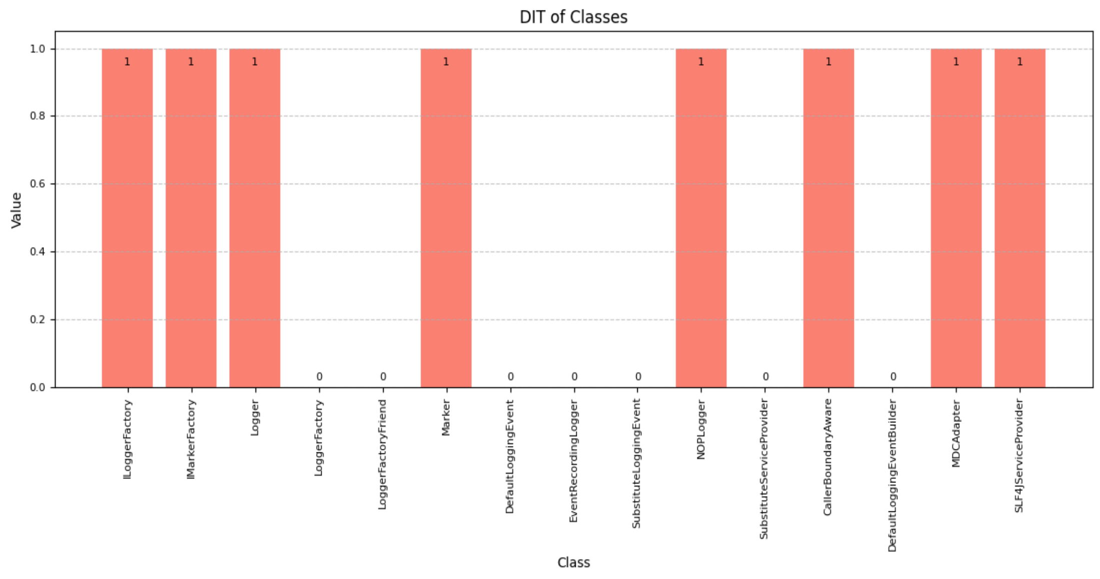
Class Element	LCOM	DIT	CBO	Complexity	Size	LOC
Marker	0	1	0	low	low	14
DefaultLoggingEvent	0.75	0	1	low	low-medium	72
EventRecordingLogger	0.625	0	0	low	low	38
SubstituteLoggingEvent	0.667	0	1	low	low-medium	59
NOPLogger	0	1	0	low	low-medium	111
SubstituteServiceProvider	0	0	1	low	low	20
CallerBoundaryAware	0	1	0	low	low	2
DefaultLoggingEventBuilder	0	0	0	low	low-medium	145
MDCAdapter	0	1	0	low	low	11
SLF4JServiceProvider	0	1	1	low	low	6

1. LCOM (Lack of Cohesion in Methods):



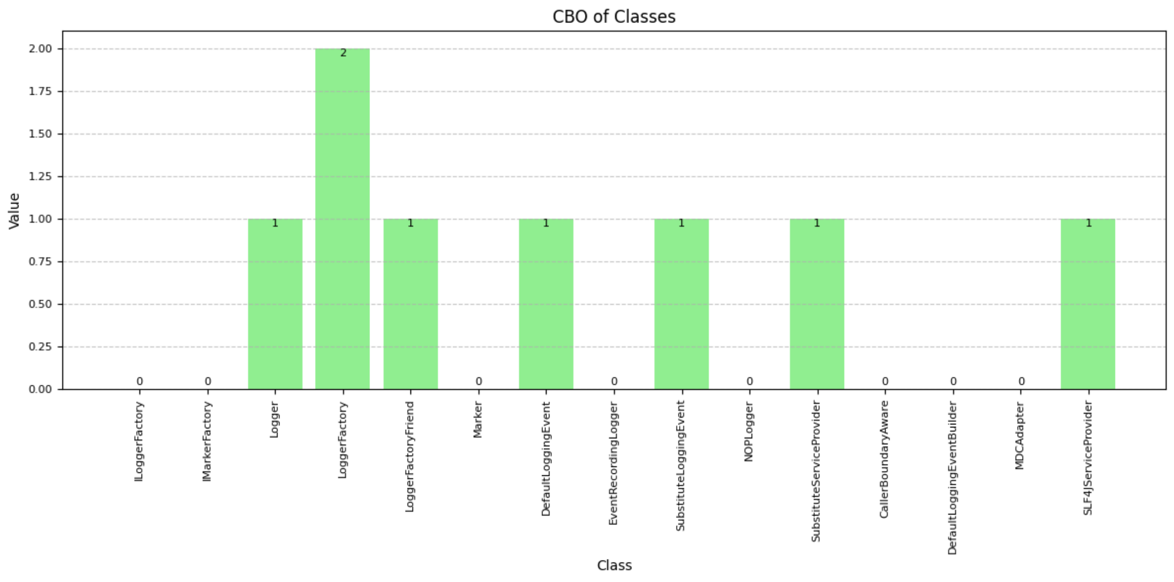
LCOM (Lack of Cohesion in Methods): The LCOM values obtained for most classes are low in most cases meaning that these classes' methods have lesser cohesion. But there are some classes like LoggerFactory, DefaultLoggingEvent, and EventRecordingLogger which have high LCOM values and so it is indicative of the fact that the classes seem to be lacking cohesion in methods.

2. DIT (Depth of Inheritance Tree):



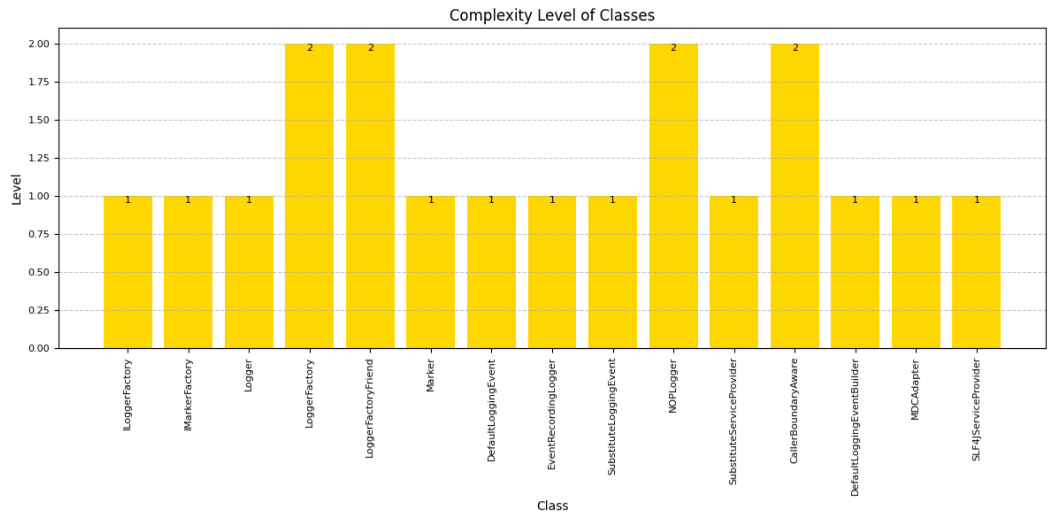
DIT (Depth of Inheritance Tree): The DIT indicates that the inheritance depth of most classes is 1 which means minimal inheritance usage. However, LoggerFactory and DefaultLoggingEventBuilder have a DIT of 2, meaning that there is more inheritance.

3. CBO (Coupling Between Objects):



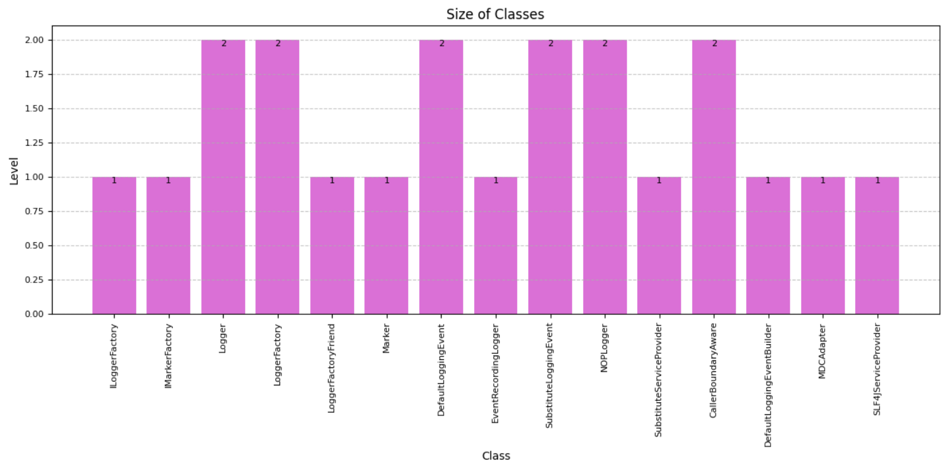
CBO (Coupling Between Objects): LoggerFactory and SubstituteLoggingEventServiceProvider classes have higher coupling meaning more interdependence of objects in comparison to the others.

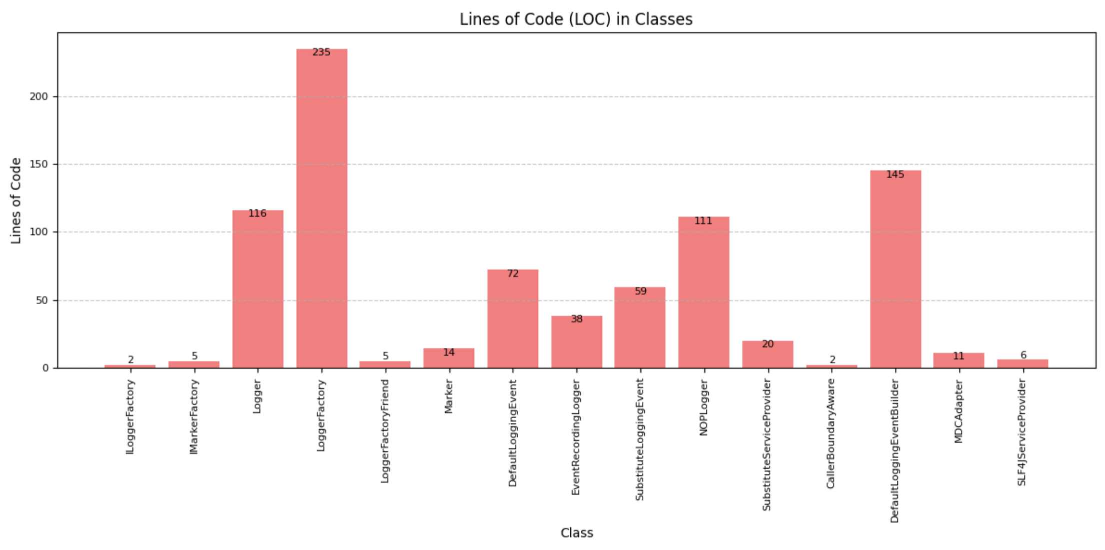
4. Complexity:



Complexity: LoggerFactory and DefaultLoggingEventBuilder have just a bit higher complexity compared to other classes, which speaks to the increased complexity of the logic or functionality implemented in these classes.

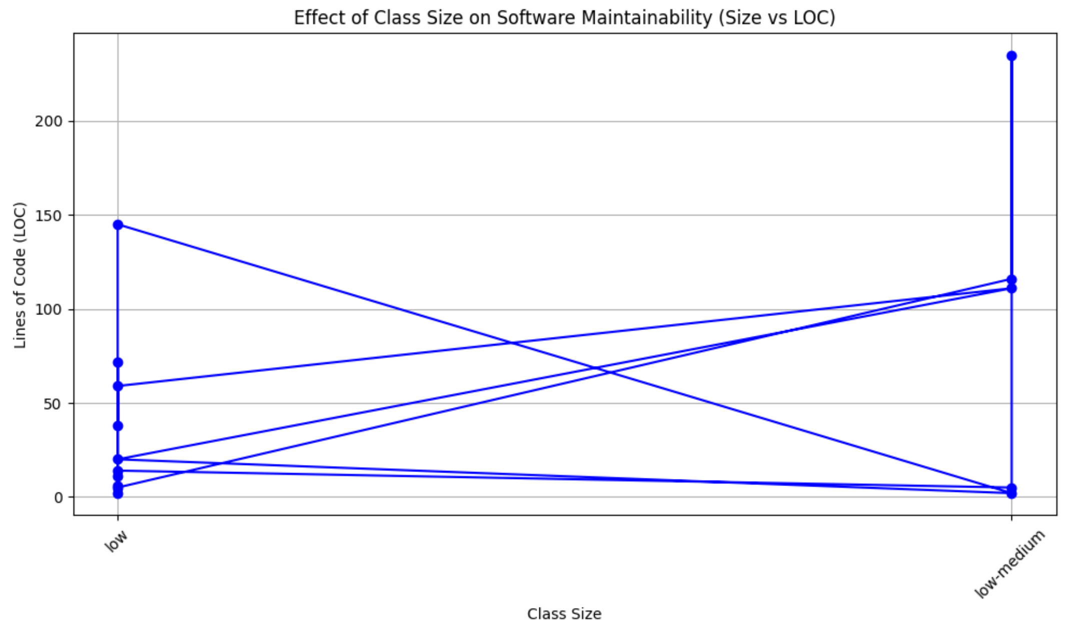
5. Size and LOC:





Size and LOC (Lines of Code): LoggerFactory On the contrary, LoggerFactory is characterized by the highest size and LOC values, which means it is the most voluminous and complex class from the code perspective.

6. Effect of Class Size on Software Maintainability:



When it comes to the relationship between the classes' size and software maintainability, the classes with big numbers of LOC have large classes such as LoggerFactory, so they probably have high complexity and low maintainability. There is a need to manage the complexity of such classes to maintain the source code of the software system.

Section – 5

5.1. Conclusion:

The analysis across multiple projects underscores a consistent trend: higher system maintainability is achieved in the case of lower class size and lower system complexity. This observation supports the need to manage the class size and complexity of the system effectively during software development to avoid maintenance and scalability issues in the future.

Among classes of Apache OpenNLP such as DocumentCategorizerDL and NameFinderDL, where high complexity and high number of source code lines are observed, lower maintainability is measured. The high level of coupling between objects also makes it difficult to carry out maintenance activities that have higher dependencies with other objects.

The same issue can be observed in the MySQL Proxy project: the BaseXaSqlConnection class, being the largest and the most complicated of all, loses its maintainability as the code becomes bigger and more difficult to understand. Others like ImmutableCoordinatorLog and ImmutableParticipantLog are smaller but also have lower maintainability with areas of method cohesion and complexity.

Apache Atlas has higher values for classes such as KafkaNotification and AtlasNotificationMessageDeserializer with higher LOC values which show reduced maintainability due to their size and complexity. On the other hand, relatively simple classes such as CommandHandlerUtility with few dependencies are mostly well maintained.

In terms of maintainability in the Simple Logging Facade for Java project, it is possible to observe that the maintainability of larger and more complex classes such as LoggerFactory and DefaultLoggingEventBuilder is lower. In contrast, more primitive and simpler classes like ILoggerFactory and IMarkerFactory are easier to manage.

Likewise, in the Mirror of Apache project, classes such as Request and Executor with high LOC because of their bigger size resulting in high LOC values have low maintainability. In contrast, HttpHeader and ContentResponseHandler have lower LOC values and are likely to be more readable and maintainable code.

The relationship between class size and maintainability further demonstrates the importance of following software engineering principles such as structuring the code into small classes, implementing class encapsulation, and avoiding code tangling and scattering. The process of extracting subsets of a large class and grouping them so that their relationships are cohesive and decoupled is a mechanism that can be used to boost the maintainability and agility of the software system.

Additionally, constant refactoring and thorough code reviews are crucial for such critical issues' elimination, as high complexity and heightened coupling issues in the codebase. By focusing on keeping classes as simple and clear as possible, teams can reduce the risk associated with large classes and work towards making the software project sustainable in the long-term.

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