

Support to development of complex software systems with
API function call recommendation

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1 Introduction

In recent years, the problem of API recommendations rise more and more in relevance in the complex software systems. When a developer writes some code to implement a specific features, he should want some suggestions about useful functions in this context. An API (Application programming interface) is a set of procedures, protocols and objects that gives to the developers the necessary building blocks to implement a specific functionality in easy and understandable way. The API depends on the language that the developer use and it usually composed by libraries with objects and methods useful for the task. The definition is very general and it may change based on the context of the developed project; so, the developer may get confusing about what kind of method or class to use or how to use them in a proper way.

The issues is how to perform a good enough recommendation in this context, balancing possible bias and put the proper hints for the developer. Moreover, the form of the recommendation is also important because in general there are variety of possible suggestion such as code snippet, patterns for the methods, enhance documentation and all things that make a recommendation really usable for the current project.

2 Related Works

Considering the state of the art, there are several approaches that face the problem that I have described in previous section. The key point is to find, on one side, a simple and effective way to extract API functions call and build the recommendation system and on other hand, is necessary to use formal and proper algorithm and techniques that produce very suitable results. In the literature, there are main approaches is first to analyze the code that you are interested in, adopting some similarity metric, optionally followed by clustering techniques and then how to represent the obtained results in form of recommendation that should be clear and effective. In next pages I present a set of approaches that follow the same main skeleton to solve the problem; what is different among them is the techniques, algorithms and produced results but they are all useful and give the flavour of the problem that I'm involved in. Table 1 gives an initial overview on the approaches, with the proposing tool, how they analyze the source code, the similarity metric and algorithm, the eventually clustering technique, the dataset considered to validate the results and the given output.

In [6], the authors extend APIMiner tool with API pattern considering Android projects as dataset. They perform the API extraction by considering FP-Growth association as main index of similarity and run it using Weka tool that consider also the relation between two API call. The recommendation system is realized by enhancing JavaDoc with the discovered pattern. Then, we have a look on [7], that perform clustering by used graph format. The authors, starting from a graph representation of the so called object usage, build a social network based on the co-existing relation among nodes. Take a general code snippet, an object usage is a list of methods that belongs to an API class that are used in the part of code that we analyze; in general, a fragment of code can contain more objects usage and this feature is represented by a co-existence relation among objects usage. So, one object usage became a node in the graph and, if there is a co-existence relation, we put an edge between them and the weight are the number of co-occurrences.

Once we have the graph representation of the code through the object usages, we can calculate similarities with two main techniques: the co-existence relation and the method call similarities. In particular, we can make a cluster among different objects usage by considering the similarity based on co-existence relation that starting from a single node, add a new one and consider the similarity by taking into account the co-existence relation until the maximum similarity is

reached. The other approach, instead, use the method call similarity measured by a Gamma index that is composed by consistent and inconsistent comparison. A comparison is consistent if the distance of two object usage that belongs to different clusters is smaller than an other pair that belong to the same cluster. In [8], the authors propose a tool for mining API and make recommendation within the JIRA project that analyze the pre-change and post changed files. The framework is composed by three main part: history based recommender, descriptor based recommender and the integrator that put all together; notice that the first two componets have the current knowledge base, represented with databases, that is used for the comparison when user try to add new features. The similarity is calculated by using Cosine similarity (that we have already used for the library recommendation part) and, after a preprocessing phase on the text of the projects, the framework performs the recommendation as top ranked methods API call coming from five Apache most famous projects. Finally, we analyze CodeBroker tool, proposed in [9] that use information retrieval techniques in order to make recommendations. The tool is based on two communication channel with the developer that is interested in API recommendation: one is an implicit where the system autonomously retrieve methods information and details from a given query. In this case it shows information organized in three layers, namely task relevance, signature details and full JavaDoc. Regarding the second channel, it is explicit because the developer can refine the query based on its current needs and the system can adapt it self to this new situation and this technique is called retrieval by reformulation. Furthermore, CodeBroker creates a discourse model to represent the projects and an user one to represent in some way the software knowledge and personal information regarding used method in the project. It uses LSA as similarity techniques to do comparison and Java core libraries as dataset to test the tool. So, all related works show different techniques to extract API call and make a something to help the developers in their work. Beyond the different implementations, most of paper share some key concepts that could help us to define the problem and introduce something new in SOTA of API call. Table 1 summarize all works and make a comparison taking into account how the authors implement similarity, what are the clustering techniques, the tool that they used and the final output.

Table 1: Summary of relevant paper

Proposed tool	Parser for code snippets	Similarity	Clustering	Dataset	Output
MAPO	JDT	Class name, Method name API call sequences	Data-driven	Java projects	Eclipse plugin that shows possible API pattern
UP-Miner	Roselyn AST parser	SeqSim technique similar sequences	Two clustering on frequent sequences with BIDE	C#	Probabilistic graph of API that can be queried
CLAMS	JDT parser	Distance matrix	LCS, HDBSCAN techniques AP-TED for top rank snippet	6 popular Java libraries	Patterns for API
APIRec	GumTree AST parser	association-based model with fine-grained code changes	association-based change inference model	50 Java project randomly from Github	Most frequent API call
Buse-Weimer algorithm	Symbolic execution for path enumeration	Distance matrix	K-medoids algorithm	Java SDK	Human readable documentation
APIMiner extension	see APIMiner	Structural similarity among API	FP-growth with WEKA tool	Android projects	Enhance documentation
JSS approach	No info	Object usages social network with co-existence relation	Co-existence relation with Modularity index method call similarity with Gamma index	Android project	API usage pattern
JIRA extension	JDT	Cosine similarity history and descriptor recommender	Integrator component based on previous weights	Apache projects	Top ranked methods
CodeBroker	Back-end search engine	Latent semantic analysis	Discourse model user model	Java core libraires	Three layered information relevant tasks, signature and JavaDoc

2.1 MAPO

In [1] the authors propose MAPO that perform methods extraction using data mining techniques, clustering them to have a more representative data and build a recommender through GEF tool. So, they divided the process into three main steps: analyzing the source code, the

API miner and API recommender. First of all, MAPO parse the source code coming from Java Github projects that use Eclipse Graphical Editor Framework (GEF), using JDT parser utilities that allow to analyze in deep a Java file and extract classes, interfaces, method invocations and method declarations. For the recommendations, MAPO considers as API method suitable for the recommender only those belong to third-parts libraries, considering the GEF framework as external, class cast and creation associated to external class and the method call that belongs to external class; basically, the authors ignore the libraries and so the internal API of the JDK. Then MAPO collects all source code by using @ as initial mark to identify a method call and # as separator between method and related class. About the conditional statements, such as if, while and so on, the authors not considered the possible relations among multiple conditions and in practice the represent them as flat code in which MAPO considers all braches. As claim by authors, this simplification is necessary otherwise the mining phase is infeasible and the API recommender is not effected by them. Once the method calls are selected, there is the problem of method overweighth and common-path overweighth that involves respectively several method call and sequence in common in the source code that can introduce bias in the result; for example, in fragment of code MAPO can select a method call only beacuse it is replicated and not for its real effectiveness. To avoid this problem, the authors select the longest sequence in common that covers also the smaller sequence of method call and, in this way, the reduce the bias. Moreover, MAPO selects only third-parties libraries using inline methodology, that consist to explore the parse tree of classes and idetify the ancestor and so excluding the JDK methods. Once MAPO have all method call, the next step is mining the sequence to produce recommendation. To do this, is not enough to consider all method sequences because this can be bring incorrect results. So, MAPO using first similarity metric, based on the name and the usage of methods to indetify similar sequence and then clusterize them by using data-driven hierarchical clustering . In particular, the authors consider three level of similitaty given by class names, method names and called API method and obtain in this way the similar sequence. Then, by using matlab tool, MAPO using classical hierarchical clustering to obtain the ranked list of representative sequences, transform them into transaction and put them into a database. Finally, the API recommender is a Eclipse plugin that allow developer to click on the method of interest , excute a query on DB to show possible uses by using sample code and developer can also see details on the proper window tab in which the API method are highlight. To validate this approach, the authors use a dataset composed by 20 projects that used Eclipse GEF, run the tool and show the effectiveness of their approach by a quantitive comparison. To reinforce the validity, they also conduct an empirical study on by considerig a set of tasks to do and select a group of Java developers that is involved to solve those tasks.

2.2 UP-Miner

A similar approach is performed by [?] in which the authors create UP-Miner tool that improve MAPO in term of accuracy. Going in deep, the aim of the authors is to achive the succitness but also the effectiveness of mined pattern that represent an enhancement of previous approach. Once the authors define API usage mining, that is the optimal number of patterns under a given threshold, they propose a clustering techinques based on BIDE algorithm. As first step, UP-Miner extracts API pattern sequences using Roslyn AST parser from the projects that compose the dataset. Then, the apply the SeqSim n-gram technique that takes two sequence computes the simitarity that is based on the shared items between them in term of objects and classes used and on the longer and consecutive subsequences rather than the shorter ones. This phase produce a weighted results that are used for clustering that are conservative on, in sense that the maximum distance between two cluster is the maximum distance between two elemets of those

cluster.

Then, UP-Minser use BIDE algorithm, that have the key concept of frequent sequence: a general sequence becomes frequent if its supersequences (namely the sequences that contains the considered sequence) is greater or less of the given threshold. Consider this, BIDE algorithm can extract the longest common sequence that are useful to divided the results into different clusters, but it is not sufficient because at this point there may be some redundant cluster. So, it is necessary to apply once again the previous phase considering the cluster as usage pattern and this two-step clustering grants an improvement in term of redundancy considering also two different threshold (one for pre-BIDE and another for post-BIDE application). Until this, UP-Miner adress the problem of coverage but the aim of the authors is to reach also the succitness of patterns. To do this, UP-Miner use a dissimilarity metric that measure the diversity of a usage pattern from another and an utility functions to maximize in order to obtain the better results, decreasing the threshold at each step of the algorithm implemented for this task. Once UP-Miner computes the correct and more succitness as possible usage API pattern, the authors show them to the developer by building a probabilistic graph in which each node is a usage pattern and the edge is weighted with certain probability. To produce this prototype and make some experiments that involves the developers in a similar way as we see in MAPO, the authors use a very large C# dataset as input files and compare their results with MAPO ones.

2.3 CLAMS

Go further with the examination of SOTA, we have also CLAMS tool proposed in [3] that follows a quite similar approach but it differs from the point of view of the results. Infact, CLAMS produce as API recommendations snippet of code that represent a pattern for a certain library. As usual, the preprocessing phase is done by analyze the AST of the source code (in case of CLAMS, projects related to 5 popular Java libraries) with a dept-first search using JDT as previous example. This phase produces snippet of code that bring all information about API implemented in the code. The similarity technique is based on Longest Common Subsequence (LCS) and is more effective rather than an analysis at source code level. By using this technique, CLAMS creates a distance matrix that is used as input by the clustering module of CLAMS, that implements the hierachical version of DBSCAN algorithm, called HDBSCAN, plus a post-clustering processing to eliminate the sequences that are identical to snippets for each cluster obtained. The aim of HDBSCAN is to isolate the less representative methods and, more in general, points into a distribution that are really far from the rest of the dataset. To do this, the algorithm uses a distance called core distance to draw a circle on the points to exlude and then computes the mutual reachability distance that reduce the presence of sparse node in the dataset. Then, by applying Prim's algorithm, HDBSCAN calculates the minimum spanning tree among the closer nodes and finally sort them by a hierarchical clustering (this phse is not present on the original DBSCAN algorithm), as well explained in the related work [ref]. There is also a useful Python library used in CLAMS that provide utility functions to make all this step in a very understandable way. The core module of CLAMS is represented by the snippet generator, that performs six main steps in order to obtain the final snippets that represent patterns. First of all, CLAMS replaces all literals present in the code with their abstract type by using srcML, a tool that produce XML file starting from a source code, and removes all comments. At the end of this step, we have code with the same structure of the original source file but more abstract. Then, CLAMS identifies API call in that code and what are not related to them and creates two lists. In the next step, the authors identify all variable in the scope of the API sequence. To finish the process, the non-API statements are removed and they put on top of snippet variable declaration related to API, plus of course the snippet of code related to those API. So, the snippet

of code that is produced in this way is composed by a sequence of variables related to API class and a possible use of them, with considering also the statements present in the original code (CLAMS retained also the structure of the code). The authors put a comment Do Something in the section of code in which the founded variables may be used.

Once CLAMS has these results, the snippet selector module find for each cluster the most representative snippets by giving them a score. To do this, the authors use another algorithm that works on AST, called AP-TED that creates a distance matrix between two clusters and from this, calculate the similarity. Finally, CLAMS ranks all representative snippet using the definition of snippet support define as follow: a snippet is supported if there is a file that contains a supersequence of it. Moreover, for human readability reason, CLAMS beautifies snippet using A-style tool, that removes useless spacing and fixes the indentation of the final snippets. For the evaluation task, the authors use 5 popular Java libraries coming from Github projects and they are Apache Camel, Drools, Restlet framework, Twitter4j, Project Wonder and Apache Wicket. In the evaluation section of their paper, the authors taking into account different clustering algorithm and make experiments with HDBSCAN, already mentioned, k-medoids that is similar to the previous one but achieve more coverage but less precision. This algorithm is based on find a central point that has the equal distance from the rest of the point, called medoid. In our case, the medoid is a particular method API call that is the most representative for the library. K-medoid algorithm uses also n-gram based technique and similarity distance matrix as HDBSCAN. To answer to the research question, the authors of CLAMS perform also a comparison with NaiveSum and NaiveNoSum approaches, that are clustering techniques less precise with respect to the HDBSCAN and K-medoids. Infact, the better results are coming out from the latter algorithms. Furthermore, the evaluation is composed by a user survey about the utility and real support given by CLAMS patterns. All this information are available at the CLAMS official site, that contains also the Github project, the original dataset and the instruction to set up the environment to launch CLAMS as standalone platform on Linux machine. As claimed by authors, this work is really interesting and flexible because it is not dependent on a specific program language. The only constrain regarding the srcML tool to produce the XML files related to API patterns, but it is not a big issue from the adaptation point of view, as we can see later.

2.4 APIrec

APIrec tool [4], instead, uses statistical techniques in order to keep trace of the context in which a developer writes its own code, by analyzing the co-occurrences and fine-grained code changes. Differently from the previous approaches, the authors keep trace of the context in which the API method call may be useful. As usual, to extract the source code from the 50 Java projects randomly selected from Github, APIrec navigates the AST of the source code using GumTree tool. Before going in deep with the implementation, the authors gives several definition that are useful to understand the behaviour and the contributions to the state of the art given by APIrec. First of all, the term API for the authors indicates both external and internal method calls and APIrec performs recommendations only if the context of API is correct for a certain situation. Regarding the AST, we have the atomic change that represent a new element on AST composed by kind of operation, AST node and label. A collection of atomic changes is called transaction and is stored in a bag, a particular data structure that we commonly find in the AST definitions. An important concept that is a key definition for the APIrec implementation is the code context, represented by code tokens related to the API that the developer is writing. Taking into account the tokens, the authors consider both the distance and the order of this, as an API method calls have a specific call order and they are really effectiveness only if there are called in the proper way. To remark this feature, APIrec gives also a weight based on how near

is the token by considering the distance matrix. Once they define this set of metric and concept, the authors show the inference model based on likelihood scores taking into account both change of the context and code.

The entire model is based on the correlation between a code token and another, expressed as we said in term of atomic changes in the AST and transactions. In particular, APIrec evaluates the probability that certain events, namely the transactions, occurs given another. This score is called association score and it is used to calculate the distance between two changes into the code as well as new methods that will take a part in the final recommendation. At the end of these computations, all possible scores and weights are calculated but it is not enough to perform the recommendations. Infact, it is necessary to apply machine learning techniques in order to train APIrec with the code changes and context. To do this, the authors use hill-climbing adaptive learning filled with three parameters: numbers of co-occurrence founded with fine-grained atomic changes, numbers of co-occurrences related to changes tokens and two weights. With this process, the necessary scores is calculated and APIrec is able to perform the recommendation by considering the most probable method calls for a certain API. The methods are also ranked by highest probability of usage but also distance, scope and dependancy are considered in the ranking phase. To support their tool, the authors conducts several experiment over a very large dataset, including also analysis regarding code change context, user empirical studies, evaluation of accuracy and predictions.

2.5 Buse-Weimer algorithm

Paper from Buse and Weimer [5] is still about API call but is focused to produce automatically a documentation for the projects in a human readable format. Once they obtain data from mining phase, the proposed algorithm extract API pattern and rearrange them in a more readable and effectiveness format. The focus of this work is on Java documentation that provides useful hints and suggestions when a developer is implementing an API functionality. Although in general the Java doc helps in this kind of activity, it often lacks in something, as the examples are too general or it not able to give a concrete hint for the problem that the developer is trying to solve. So, the aim of the authors is to produce an enhanced version of documentation that is really useful for the developers, starting from retrieve the API patterns, defined as the sequence of function call for a certain API class, called target class. Once this first step is done, the algorithm tries to produce an human-written documentation for the API, taking into account some characteristics such as the lines of code, that are 11 on average but 5 for the median. Moreover, the authors considers also the abstract initialization, abstract usage and exception handling. All this information is extracted using JDK utilities and they are validated by the authors, putting more effort on the human aspect. To validate the results, they involve over 150 developer and collect their answers about the proposed results. By analyzing these statistics, a typical developer wants a multiple uses for a certain class or API method and not only one, that may be not useful for his particular context. Another key point is the conciseness of the suggested snippet of code, as well as the readability and variables names that must be related to the context, also including temporary ones to improve the readability. So from this survey, we can identify four key points to achieve the human-written documentation: size of the code, readability, representativeness and concreteness.

To reach these goals, let look to the algorithm implementation, that the authors divide into four main step, the path enumeration, predicate generation, clustering and finally the output documentation. Starting from the path identification, they scan the code and identify acyclic part of the code that represent a path for the target class. Notice that this approach can lead some bias but it happens in practice and the authors choose to stay close with respect to real

implementation. So, they use intensively human users to perform test and to measure the accuracy of their proposed algorithm. As the previous approaches, they parse the code and cluster the significant result with a distance matrix in order to build the related documentation. As the purpose is different from previous works, they are adding some clustering also on predicate and represent the abstract pattern as a graph. Then they compute symbolic execution over these paths in order to produce interprocedural path predicates that are logical formulas used to represent the code and in particular, if a certain statement is reachable or not. From this abstraction, the algorithm computes use seeds that are local instantiations of fields, objects and whatever is related to the target class. Finally, from these it produces concrete uses, the real hints about the target class, that are stored in graph form in which edges keep trace about what happens before and so, in this way, we have the context as well as the chain of methods necessary to implement the features related to the target class. To have better results, however, it is not enough to produce usage examples, as we seen so far with the other related works. Clustering is necessary to avoid heavy computation, and the proposed algorithm exploits the well-known k-medoids algorithm with some modifications, as the original algorithm is not suitable to detect distance about objects. The distance matrix that is taking into account by the k-medoids algorithm is based on the happens before relation obtained from the graph. So, at the end of this computation, the algorithm obtains the cluster and summarizes them into abstract uses, represented once again in graph form. The final step of the proposed algorithm is to produce the documentation. Starting from the abstract uses, it uses a topological approach to avoid the cycle and branches that appear in the code, as the final recommended documentation about the target class must be a flat file. Using this approach, the authors are able to retrieve a Java documentation related to the target class and respect also the Java syntax, so they avoid malformed documentation. Moreover, with this approach, the algorithm handles the exception treatment with try catch clauses, that are put always in the correct order. As said before, the focus of this approach is on readability of the recommendation from human's perspective, so the authors set up a very big evaluation framework composed by 47 SDK classes and dataset, the eXoaDOC tool as concurrent approach and over 150 people as tester. The threats rise up from this evaluation are related to the validity of dataset (it may be not indicative and it doesn't represent all possible situation) and the background of the developers chosen for the evaluation (not expert in the field). However, this approach is useful to understand the concept of readability that is very useful for my approach.

2.6 APIMiner

2.7 JSS approach

2.8 Jira extension

2.9 CodeBroker

3 Problem definition

3.1 Concept of API

3.2 Concept of Pattern

4 Code clone with Simian tool

4.1 About code cloning

4.2 Simian overview

As we see from the related works, we can perform recommendation at different levels of abstraction (pattern, methods, code snippets) in order to give a complete and useful hints to a developer. If we look at level of code, there are many tools that perform code clone analysis by retrieving some information about lines of code in the same project or file by file. I analyze Simian tool, a project developed in Java that performs this kind of analysis for many languages as Java, C, C#, Ruby, JavaScript, COBOL, Lisp, SQL, Visual Basic. Once I download the .tar file, I simply run the simian.jar file using command line interface in the directory that I'm interested to analyze. We can enhance the Simian analysis by using a lot of options such as fix a threshold for the number of duplicated lines, ignore literals or string case, numbers, parenthesis and so on plus specifying singular files. For my analysis, I focus the attention on Java projects and I run the tool using options only related to Java code, so I discarded specific options for other tool (for example C++ or Ruby) or options that are too restrictive such as ignoreSubtypesNames or ignoreLiterals. To make a better analysis, I consider both projects that we can suppose are similar in some way and very different projects that implements different functionalities. Table 3 and Table 4 describe respectively the options that I have used to perform the comparison among projects and projects characteristics and similarities while Figure 2 represent the related output, both in case of strong similarity and no common lines of code. Once we are in the directory that contains the projects to analyze, the command is `java -jar simian.jar path` and the options that we want to use.

Table 2: Simian options used in the experiment

Option name	Default value	Description
-threshold	6	This option fix an lower bound on the number of duplicated lines of code (if present)
-formatter	none, possible values: plain, xml, emacs, vs (visual studio), yaml, null	This option is used to obtain results in a specified format
-reportDuplicateText	disable , type + to add	With this option, the duplicated lines of code present in all projects are printed on the console
-language	disable , type + to add	This option specify the language of the input files to compare
-defaultLanguage	disable , type + to add	If not file type is not specified, Simian inferred the type and set it as default
-failOnDuplication	able , type - to remove	If this option is able, it causes an exception when the checker finds duplicate code
-reportDuplicateText	disable , type + to add	With this option, the duplicated lines of code present in all projects are printed on the console
-ignoreRegions	disable , type + to add	It ignores block in regions structures (only for C# programming language)
-ignoreBlocks	disable , type + to add	It excludes specified blocks from the comparison (start/end line must be specified)
-ignoreCurlyBraces	disable , type + to add	The curly braces are ignored so it should be match as duplicate line
-ignoreIdentifier	disable , type + to add	With this option, the variable with different (identifiers match as equal
-ignoreIdentifierCase	able, type - to disable	This option not consider the case of identifiers present in the code: so Name and name are considered equal)
-ignoreStrings	disable , type + to able	This option consider all strings in the comparison and doesn't take care about the form in which are write
-ignoreStringCase	able, type - to disable	Same as previous option but consider the upper and lower case as the same
-ignoreNumbers	disable, type + to add	This option considers different numbers as equal
-ignoreCharacter	disable, type + to add	With this option, all character type match as equal
-ignoreCharacterCase	able, type - to disable	Same as ignoreStringCase but consider char by char. Useful for more precise analysis
-ignoreLiterals	disable, type + to add	All literals should be seen as equal for Simian
-ignoreVariableNames	disable, type + to add	This option allow to Simian to see different variable names as equal
-ignoreModifiers	able, type - to disable	This option doesn't consider modifiers of methods (public, private, protected as element of diversity in the code

Table 3: Projects considered in the comparison

Projects name	Main features	Similarity level (duplicated LOC)
ADTPlugin, ModiscoPlugin	Plugin projects created with same wizard	39 lines of code in common
CyberGea, NeoEMFExample	Cybergea: Plugin, Servlets and JDBC NeoEMF: Metamodels, Neo4J facilities, EMF framework	No lines in common
CyberGea, Scuna project	Cybergea: Plugin, Servlets and JDBC SCuna: Swing GUI and JDBC	12 lines on common (basic JDBC statement)
Simple Servlet, ServletSession	Web projects with servelts	35 lines of code in common

```

@Override
public void init(ServletConfig config) throws ServletException {
    super.init(config);
    startup = Calendar.getInstance();
}

// <editor-fold defaultstate="collapsed" desc="HttpServlet methods. Click on the + sign on the left to edit the code.">
/**
 * Handles the HTTP <code>GET</code> method.
 *
 * @param request servlet request
 * @param response servlet response
 * @throws ServletException if a servlet-specific error occurs
 * @throws IOException if an I/O error occurs
 */
@Override
protected void doGet(HttpServletRequest request, HttpServletResponse response)
    throws ServletException, IOException {
    processRequest(request, response);
}

/**
 * Handles the HTTP <code>POST</code> method.
 *
 * @param request servlet request
 * @param response servlet response
 * @throws ServletException if a servlet-specific error occurs
 * @throws IOException if an I/O error occurs
 */
@Override
protected void doPost(HttpServletRequest request, HttpServletResponse response)
    throws ServletException, IOException {
    processRequest(request, response);
}

/**
 * Returns a short description of the servlet.
 *
 * @return a String containing servlet description
 */
@Override
public String getServletInfo() {
    return "A kind servlet";
}
=====
Found 112 duplicate lines in 24 blocks in 3 files
Processed a total of 252 significant (559 raw) lines in 4 files
Processing time: 0.222sec

```

Figure 1: An example of simia tool output

In particular, I showed that the projects that follow the same structure such as Plugin projects using the same wizard for the creation or the same framework shared same lines of code while in case of very different projects, as in the comparison between CyberGea and NeoEmf, there are no commons lines of code.

5 Proposed approach

5.1 Overview

After the problem statement and an brief description of Simian tool, let me present a possible approach to solve the problem of API function call recommendations. This approach, described in Figure 2, exploits the CLAMS work, in particular the patterns extracted as output, plus the code cloning features provided by Simian. So, at the beginning of the process, we have the patterns files and the devoper's file, represented by a single string. Notice that with this method we keep trace on the context in which the user is developing. Then, all these files is used to extract the recommendations in form of patterns by using Simian integrated in Eclipse platform, following options that I specify in next sections. Basically, at the of this phase, Simian retrieve the cloned clone between the developer's file and the CLAMS patterns related to the library that the user is implemented. By using these file, I perform recommendations by remove the cloned part and suggest to the user the new lines of code that represent the missing pattern for the user. In next sections, I going in deep to describe the entire system and how the integration of Simian and CLAMS works in practise.

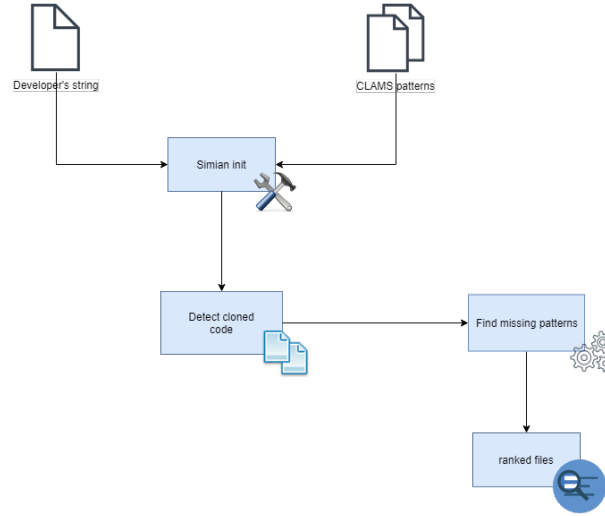


Figure 2: Recommendation for a single file using Simian and CLAMS

5.2 Input files

About input files that are necessary to initialise the tool, we have from one side the developer's file with the real snippet of code that he is implementing and may want support for this. On other hand, there are patterns mined by CLAMS, in form of ranked Java files sorted by rational specified in CLAMS paper. These file contains patterns, defined as sequence of API method calls that define, instantiate and using class belonging to the APIs contained in the developer's string. The number of these file and also their dimensions in term lines of code depend on the considered libraries. As Simian is a tool based on file comparison, I need to use temporary files of Java to do the comparison; after the process, the files are destroyed.

5.3 Simian within Eclipse platform

Once we define the input, there is another step in order to use Simian to do API recommendations: the integration with Eclipse platform to have a more flexible and usable version of the tool. As I said in previous section, the basic version of Simian is a jar file that I launched from the terminal console with different options (see the Table 1). Although it is very easy to use, in this version is not integrable with the other parts of the system and it is necessary to integrate directly the Simian jar file, available on this site <https://www.harukizaemon.com/simian/javadoc/index.html>. To keep the integration with a Maven project, we create a repository that contain the update version of this jar and put it as reference in the POM file of the project.

Following this documentation, we have the following main classes:

Table 4: Overview about Simian classes

Simian class	Description
Auditstener	This class is necessary to initialise Simian tool and collect all notification from events that occur
Block	This class represents the duplicated block of code as an object and we can interact using method utilities
FileLoader	It is used to load all files for the comparison, with the method load
Checker	This class is used to perform the real comparison by calling the method check() on preloaded files
StreamLoader	Once we load files and create the Checker, this class load them into the Checker
Options	A data structure that encapsulates all options enabled for the comparison
Option	This class represents a single option and we can specify it by accessing to a static field
Language	This class contains static fields to set all supported languages as type of input files
CheckSummary	It contains all statistical data such as cloned code, number of total files, requested time and duplicated files

5.4 CLAMS adaptation

Regarding the CLAMS output, I describe the original structure as well as the necessary modification to integrate it in our approach. The authors, differently from other works, provide the complete source code and commands to set up the entire environment to have CLAMS working on Linux . CLAMS is written in Python and uses srcXML and Astyle to produce xml files and to formatter in a human-readable way the code respectively, but as claimed by the authors, there is no really constrain about the technologies to use in case of a new implementation. As input, CLAMS takes two kind of files: client files, that represent the real project on Github related to the dataset that authors use for evaluation phase while example files are used to find the method call and for the ranking phase. All these files are collected in a folder, that CLAMS loads by getting the path. Moreover, there is a namespace file that identify the name of classes used in the clients and example files by using their complete namespaces such as org.codehaus.jackson. The last input used by the main.py file, that is used to initialise the platform, is the methods calls and caller are represented by an .arff file, using in the machine learning domain.

There is a phase of preprocessing in which CLAMS extracts API call and their AST using JDT utilities and represent them in xml using srcXML. The core of the project is the snippet generator module (represented by summarise.py file) that takes as input a source code file (java in this case) and using srcXML they first replace literals with xml types and delete comment. Then , they separate the API code from code that doesn't contain API call and highlights the variable in local scope of API. Finally, the code without API call is removed and Clams add some comments near the API statement and needed variables. Notice that their approach considers also the classical statement like if-else structure as a part of API statement. For clustering, they use both HDBSCAN and k-medoids algorithm that are quite similar and differs only in the preci-

sion of the returned snippet (HDBSCAN is more accurate but k-medoids covers more methods). For both of them, the authors import Python libraries that implement these algorithm quite well and we can switch the algorithm by change the parameter in the main.py. Moreover, they have the file ranking.py to order the generated snippet. The rank is based on the example files that contains a sequence of API call; if the sequence within the file is a super-sequence of the sequence of snippet that we considered, so this snippet is supported, and its rank is increased. In the result folder, CLAMS put the library that we want to analyze, the methods, the source file (both in .java and xml format), some json file that represent all information about a method (class, package, rank, id) and the arff file related to the library.

For the integration step in our platform, it is necessary to slightly modify the original approach to have better results. In particular, if we use the pattern of CLAMS as they are, there are some bias because, through srcML, CLAMS substitutes the literals with its own type and Simian is not able to detect them as cloned code, even using all available options regarding the code. So, to avoid this situation, we must modify the function that substitute literals, putting some default value instead of srcML types. This modification doesn't affect the validity and accuracy of extracted path because is just a matter of modify literals with another. Furthermore, we have to modify the clients files with our dataset that is composed by projects that use MQTT and some Json libraries.

5.5 API recommendations

At the end of these preparatory phases, I can start with describe the core of this project, the API recommendations. Once the Simian is launched, it performs the detection of code cloning activity on the CLAMS patterns files and the developer's code snippet. Notice that the notion of cloned code depends on the options that we have selected and turn on as the Table 4 describes. The mandatory options to enable is the threshold, that set the minimum line of code in commons, reportDuplicateText, otherwise we couldn't show and manipulate the result and language that is Java because we analyze projects related to it. Other options, such as the strings, identifiers or modifiers that should be introduced in the comparison, can be enable with respect to the level of cloning that we want to reach. To find useful results, it is necessary to set at least ignoreIdentifiers, ignoreIdentifierCase, ignoreLiterals, ignoreVariableName, ignoreNumbers and ignoreModifiers because Simian goes beyond the developer personal implementations and looking only for the structure of the code, in order to use the concept of pattern in a more effective way. Furthermore, I compare the pair developer' snippet - pattern because some CLAMS pattern includes some duplicated lines of code and this can bring some bias. Once we load the files, the check is performed and the results that include lines of code, name of pattern file and time to perform the comparison. At the end of this step, we have the patterns (a complete one or only partial) that the developer is start to implement and we can dischard this from the comparison, as the developer is not interested to see what he have done so far. Moverover, new pattern can introduce something new or suggest an alternative implementation for the developer. The last step is remove the duplicated line of code from the suggested pattern and show to the developer only the novel part, in form of some that integrate his code or completely new pattern, related of course to the APIs that he is implementing. About the ranking, we order the pattern by considering the number of cloned lines, so the first pattern is the contains more duplicated lines rather than second and so on. The rank phase is simply performed on the APIRecommendation object that we produce as output.

Current file	CLAMS pattern
<pre> Twitter mTwitter; final String CONSUMER_KEY; final String CONSUMER_SECRET; final Action action; final User first_source; final int sources_length; </pre>	<pre> { Twitter mTwitter; final String CONSUMER_KEY; final String CONSUMER_SECRET; mTwitter = new TwitterFactory().getInstance(); mTwitter.setOAuthConsumer(CONSUMER_KEY, CONSUMER_SECRET); } </pre>

New pattern found	Similar pattern
<pre> mTwitter = new TwitterFactory().getInstance(); mTwitter.setOAuthConsumer(CONSUMER_KEY, CONSUMER_SECRET); </pre>	<pre> { AccessToken a; String CONSUMER_KEY; String CONSUMER_SECRET; Twitter twitter; twitter = new TwitterFactory().getInstance(); twitter.setOAuthConsumer(CONSUMER_KEY, CONSUMER_SECRET); twitter.setOAuthAccessToken(a); Twitter mTwitter; final String CONSUMER_KEY; final String CONSUMER_SECRET; mTwitter = new TwitterFactory().getInstance(); mTwitter.setOAuthConsumer(CONSUMER_KEY, CONSUMER_SECRET); } </pre>

```

package com.nookdevs.twook.services;

import java.util.ArrayList;
import twitter4j.DirectMessage;
import twitter4j.ResponseList;
import twitter4j.Twitter;
import twitter4j.TwitterException;
import android.util.Log;

import com.nookdevs.twook.activities.Settings;
import com.nookdevs.twook.activities.Tweet;
import com.nookdevs.twook.utilities.Utilities;

public class DirectMessagesDownloaderService extends MessagesDownloaderService {
    private static final String TAG = DirectMessagesDownloaderService.class
        .getName();

```



```

@Override
protected ArrayList<Tweet> getTweets() {
    ArrayList<Tweet> tweets = new ArrayList<Tweet>();
    Settings settings = Settings.getSettings(this);
    // The factory instance is re-useable and thread safe.
    final Twitter receiver = settings.getConnection();
    ResponseList<DirectMessage> messages;
    try {
        messages = receiver.getDirectMessages();
        for (DirectMessage message : messages) {
            final Tweet tweet = new Tweet();
            tweet.setMessage(message.getText());
            tweet.setUsername(message.getSender().getName());
            tweet.setImage(Utilities.downloadFile(message.getSender()
                .getProfileImageURL()));
            tweets.add(tweet);
        }
        return tweets;
    } catch (TwitterException e) {
        Log.e(TAG, e.getMessage());
        return new ArrayList<Tweet>();
    }
}

```

```

final String TAG;
final Twitter twitter;
try {
    Query query = new Query(((SearchActivity)getMainActivity()).getSearchTerm());
    QueryResult result = twitter.search(query);
    return Utilities.tweetsToTweets(result.getTweets());
} catch (TwitterException e) {
    Log.e(TAG, e.getMessage());
}

```

6 Validation

6.1 Evaluation framework

6.2 Comparing results

6.3 Performances

7 Conclusion

References

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8 References

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