University of Ljubljana
Faculty of Computer and Information Science

Žiga Makuc

Methods to Assist Plagiarism Detection

diploma thesis

university study programme
computer and information science

Mentor: doc. dr. Dejan Lavbič

Ljubljana, 2013

Univerza v Ljubljani
Fakulteta za računalništvo in informatiko

Žiga Makuc

Metode za pomoč pri zaznavi plagiatorstva

diplomsko delo

univerzitetni študijski program
računalništvo in informatika

Mentor: doc. dr. Dejan Lavbič

Ljubljana, 2013

Besedilo je oblikovano z urejevalnikom besedil LaTeX.

Univerza v Ljubljani
Fakulteta za računalništvo in informatiko

Tržaška 25
1001 Ljubljana, Slovenija
telefon: 01 476 84 11
01 476 83 87
faks: 01 426 46 47
01 476 87 11
www.fri.uni-lj.si
e-mail: dekanat@fri.uni-lj.si

Št. naloge: 01923/2013
Datum: 03.04.2013

Univerza v Ljubljani, Fakulteta za računalništvo in informatiko izdaja naslednjo nalogo:

Kandidat: **ŽIGA MAKUC**

Naslov: **METODE ZA POMOČ PRI ZAZNAVI PLAGIATORSTVA**
METHODS TO ASSIST PLAGIARISM DETECTION

Vrsta naloge: Diplomsko delo univerzitetnega študija

Tematika naloge:

Odkrivanje plagiarizma je zahtevno opravilo, ki ne vključuje zgolj zbiranja in analize podatkov, ampak je predvsem pomembna faza potrditve suma goljufije in preiskovanja podatkov. Med obstoječimi pristopi najdemo številne rešitve, ki omogočajo ugotavljanje podobnosti v programski kodi in tudi prostem tekstu. Manjkajoča funkcionalnost pa je zagotovo vizualizacija podatkov in poenostavljeno preiskovanje podatkov. V okviru diplomske naloge pripravite prototip, ki omogoča uvoz podatkov iz obstoječe storitve za ugotavljanje podobnosti v programski kodi Moss, rezultate obogatite s podatki iz družabnih omrežij Facebook in Twitter ter spletnega iskalnika Google in poskrbite za ustrezno vizualizacijo. Rešitev naj bo namenjena predvsem učiteljem, kjer naj bo ključni cilj poenostavitev izvajanja procesa odkrivanja plagiatov z inovativnimi vizualizacijami sumov plagiatov, ki jih lahko uporabnik podrobneje pregleda z obogatenimi podatki in potrdi oz. ovrže.

Mentor:

doc. dr. Dejan Lavbič

Dekan:

prof. dr. Nikolaj Zimic

Fakulteta za računalništvo in informatiko • UNIVERZA V LJUBLJANI • 2

Univerza v Ljubljani
Fakulteta za računalništvo in informatiko

Tržaška 25
1001 Ljubljana, Slovenija
telefon: 01 476 84 11
01 476 83 87
faks: 01 426 46 47
01 476 87 11
www.fri.uni-lj.si
e-mail: dekanat@fri.uni-lj.si

No. of dissertation: 01923/2013
Date: 03.04.2013

University of Ljubljana, Faculty of Computer and Information Science issues the following dissertation:

Candidate: **ŽIGA MAKUC**

Title: **METHODS TO ASSIST PLAGIARISM DETECTION**

Type of dissertation: Undergraduate dissertation

Topic of the thesis:

Plagiarism detection is demanding task, consisting not only of collection and analysis of data but also confirmation and investigation of plagiarism. The existing approaches enable us identification of similarities in source code and also text. Visualization and simplified traversing the data is certainly one of the missing functionalities. Student should develop a prototype that enables importing the data from existing service for plagiarism detection Moss. This data should be then further enriched with additional information found on Facebook and Twitter social networks and also Google search engine. The end users of the implemented solution will be mainly teachers and professors where main goal is to simplify the process of plagiarism detection with introduction of innovative visualisations of identified cases of plagiarism. These cases should be than further reviewed with additional enriched information by end user who also confirms or rejects the identified plagiarism.

Mentor:

Ass. Prof. Dejan Lavbič, PhD

Dean of Faculty of Computer and Information Science

Prof. Nikolaj Zimic, PhD

Fakulteta za računalništvo in informatiko
2
UNIVERZA V LJUBLJANI

Izjava o avtorstvu diplomskega dela

Podpisani Žiga Makuc, z vpisno številko **63070200**, sem avtor diplomskega dela z naslovom:

Methods to Assist Plagiarism Detection

S svojim podpisom zagotavljam, da:

- sem diplomsko delo izdelal samostojno pod mentorstvom doc. dr. Dejana Lavbiča
- so elektronska oblika diplomskega dela, naslov (slov., angl.), povzetek (slov., angl.) ter ključne besede (slov., angl.) identični s tiskano obliko diplomskega dela
- soglašam z javno objavo elektronske oblike diplomskega dela v zbirki "Dela FRI".

V Ljubljani, dne 21. junija 2013

Podpis avtorja:

Ker je diplomska naloga tudi zaključek študija, bi se na tem mestu rad zahvalil vsem, ki so mi kakor koli pomagali pri doseganju tega cilja. Na prvem mestu bi se rad zahvalil vsem članom svoje družine, saj so me podpirali v celotnem obdobju študija in seveda tudi pred tem. Poleg tega bi se rad zahvalil tudi prijateljem in sošolcem, ki so mi stali ob strani in poskrbeli, da sem uspešno prišel do tega cilja. Ne nazadnje gre zahvala tudi Lidiji Šega, ki je svoj čas in trud vložila v lektoriranje tega dela.

Zahvaljujem se tudi mentorju, doc. dr. Dejanu Lavbiču, ki je s svojimi strokovnimi komentarji in predlogi pripomogel k uspešno izdelani diplomski nalogi.

Contents

List of Used Acronyms

API	Application Programming Interface
CSS	Cascading Style Sheets
CSV	Comma-Separated Values
Captcha	Completely Automated Public Turing Test to Tell Computers and Humans Apart
D3	Data-Driven Documents
DBMS	Database Management System
DOM	Document Object Model
FB	Facebook
FPDF	A PHP class which allows to generate PDF files
FTP	File Transfer Protocol
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
ID	Identifier
IP	Internet Protocol
JPlag	A system that finds similarities among multiple sets of source code files
JSON	JavaScript Object Notation
Moss	Measure of Software Similarity
MySQL	My Structured Query Language
OAuth	An Open Standard for Authorization

PDA	Plagiarism Detection Assistant
PDF	Portable Document Format
PHP	An Open-Source Server-Side Scripting Language
SQL	Structured Query Language
SSL	Secure Sockets Layer
SVG	Scalable Vector Graphics
TW	Twitter
UNIX	A Multitasking, Multi-User Computer Operating System
URL	Uniform Resource Locator
Wkhtmltopdf	Simple Shell Utility to Convert HTML to PDF
X11	The X Window System
XML	Extensible Markup Language
XVFB	X Virtual Framebuffer
cURL	A command line tool for transferring data with URL syntax

Povzetek

Dandanes je povezovanje ljudi vedno lažje in bolj dostopno. Z uporabo interneta in telefonov lahko študentje in dijaki lažje komunicirajo in si izmenjujejo sporočila. Ker je sama komunikacija bolj enostavna, dostopnejša in hitrejša, se to pozna tudi pri šolskem delu. Učenci si veliko lažje pomagajo med seboj, saj se lahko slišijo preko telefona ali interneta praktično kadarkoli, ne glede na to, kje so. Pri šolskem delu je pa zelo tanka meja med pomaganjem in prepisovanjem.

V diplomskem delu se ukvarjam predvsem s tem, kako bi lahko poenostavil in izboljšal proces ugotavljanja plagiatorstva. Razvita je bila spletna aplikacija, ki s pomočjo zunanjega ponudnika omogoča ugotavljanje podobnosti in se poveže tudi s socialnimi omrežji kot sta Facebook in Twitter. Aplikacija je poimenovana *Plagiarism Detection Assistant*, ali po slovensko *Asistent pri zaznavanju plagiatorstva*. Ta aplikacija je narejena za ugotavljanje podobnosti v programski kodi. V ta namen se uporablja orodje Moss (prej omenjeni *zunanji ponudnik*), ki sprejme vhodne datoteke, kot izhod pa vrne poročilo o podobnosti.

Sama aplikacija je zasnovana tako, da oseba, ki preverja podobnost, naredi nov projekt (*ime predmeta*) in doda domače naloge. Pri vsaki domači nalogi lahko v aplikacijo naloži učenčeve domače naloge (*datoteke*), ki jih potem preveri s pomočjo orodja Moss. To se naredi avtomatično s klikom na gumb, ki to preverjanje zažene. Aplikacija potem to poročilo avtomatično pregleda in prepiše vse ustrezne podatke v svojo podatkovno bazo. Te pridobljene informacije lahko nato uporabnik vizualizira.

Na voljo sta dva tipa vizualizacije. Prvi je vizualizacija v obliki *grafa*. V tem primeru vsako vozlišče predstavlja učenca, povezava med dvema učencema pa predstavlja zaznano podobnost v njuni kodi. Ker aplikacija omogoča več domačih nalog, se lahko potem jasno vidi, kdo je od koga prepisoval skozi celoten semester ali leto. Drug način vizualizacije je tako imenovana *sopojavitvena matrika*, pri kateri leva navpična os in desna vodoravna os predstavljata učence. Sama vizualizacija je predstavljena kot matrika, kjer je potem prikaz plagiatorstva predstavljen v kvadratkih. S klikom na osebo (torej v primeru grafa na vozlišče, v primeru matrike pa na ime, ki je napisano ob matriki) se odpre nova stran, kjer so podatki o osebi. S klikom na povezavo (v primeru grafa povezava med vozliščema, v primeru matrike pa kvadratek) se odpre nova stran, kjer so podatki o tem ujemanju.

Stran, ki prikazuje podatke o osebi, vsebuje več informacij. Sama stran je razdeljena na tri razdelke. Prvi prikazuje ime in priimek ter vpisno številko učenca. Poleg tega je prikazana tudi profilna slika, če je le ta na voljo iz socialnih omrežij. Drugi razdelek je namenjen socialnim omrežjem. Aplikacija podpira povezavo s spletno stranjo Facebook in Twitter. Uporabnik ima možnost avtomatično poiskati profile na teh socialnih omrežjih - glede na ime učenca. Za dobljene profile lahko preveri, če so ustrezni, in pravilnega potrdi, nepravilne pa zavrže. Uporabnik ima opcijo tudi ročno dodati profil. Tretji razdelek vsebuje informacije, s katerimi drugimi učenci je zaznana podobnost v kodi. Uporabnik lahko nato pregleda dejansko kodo in vidi podobnost (rezultat, ki ga vrne Moss). Nato lahko potrdi ta plagiat kot resničen ali pa ga zavrne. Tako se sestavi seznam ujemanj, ki mu pomaga pri kasnejšem ugotavljanju plagiatorstva.

Stran, ki prikazuje podatke o ujemanju dveh oseb, je tudi razdeljena na tri razdelke. Prva dva vsebujeta informacije o teh dveh osebah. Tretji pa vsebuje informacije o ujemanjih na socialnih omrežjih. Če sta ti dve osebi prijatelja na socialnem omrežju Facebook ali Twitter, se to izpiše. Poleg tega se tukaj izpišejo tudi podatki o številu ujemanj njunih imen in priimkov na iskalniku Google. V tem razdelku pa so tudi podatki, pri katerih domačih

nalogah sta ta učenca imela ujemanje v kodi.

Poleg tega ima uporabnik možnost generiranja poročila, v katerem so zajeti vsi pomembni podatki. Vidi se, kateri učenci so si med seboj pomagali (če so povezani v skupine, se vidi tudi to), kakšne so bile podobnosti med njihovimi deli ter izris obeh vizualizacij.

Namen diplomske naloge je torej bil predstaviti različne načine, kako lahko *poenostavimo preverjanje plagiatorstva* (oziroma naredimo to delo bolj človeku prijazno) in v to vključimo še *socialna omrežja*, ki lahko podkrepijo naše domneve. Seveda je po zaključenem preiskovanju potreben še *razgovor* s temi učenci. S tem potem dejansko potrdimo ali zavržemo sum o plagiatorstvu. Aplikacija vsebuje mnogo funkcionalnosti, ki so opisane v sami diplomski nalogi. Pri razvoju teh funkcionalnosti sem naletel tudi na mnogo težav. Določene so se dale odpraviti, določene so bile pa rešene tako, da kljub tej težavi zadovoljijo potrebe uporabnika - vendar ne na najbolj optimalen način. Ob razvoju aplikacije se je porodilo tudi mnogo drugih idej, ki pa trenutno še niso razvite, vendar pa je opisano, kako bi se jih dalo implementirati.

Iz tega je razvidno, da določene funkcionalnosti omogočijo *boljši pregled* nad delom učencev. Kakšne bi bile sankcije za ugotovljeno plagiatorstvo v tem trenutku niti ni pomembno, saj se mi zdi, da je bolj pomembno to, da uporabnik ugotovi, *zakaj je prišlo do plagiatorstva*. Tako orodje namreč odkrije plagiate in s tem omogoči uporabniku, da povabi učence na razgovor in tako razkrije *razloge za plagiatorstvo*. S tem v mislih potem tudi ve, kako pravilno pristopiti k podaji nalog naslednje leto, da bi že vnaprej preprečil plagiatorstvo in tako učencem omogočil *pravilen pristop k izdelavi nalog*.

Ključne besede:

plagiatorstvo, vizualizacija, Moss, Twitter, Facebook, Google

Abstract

Modern technologies enable students to interact with each other much easier than in the past. This enables students to help each other with their school assignments, which can quickly lead to *plagiarism*. The purpose of this diploma thesis was to create an application which simplifies detecting plagiarism. It also has some functionalities which connect to *social media websites* and can add valuable information in detecting plagiarism.

The application is designed in such a way that user can upload student submissions and then check them for plagiarism. This application supports *source code plagiarism detection*. After submissions have been checked (with external provider - Moss), the user can create visualisations which are based on retrieved data. Currently two types of visualisations are implemented - *Graph visualisation* of plagiarism and *Co-Occurrence Matrix visualisation*. The user can then check each plagiate and confirm or reject it. With that he can later create a list of persons which are potential plagiators and invite them on an interview to *verify the suspicion* of plagiarism. This application supports multiple assignments, so that the user can track each person for plagiarism through all assignments.

Connection to social media websites such as Facebook and Twitter is also implemented. With that the user can retrieve information whether two persons *are friends* on those sites. Also a number of Google results including their names is provided.

This leads to conclusion that different functionalities enable the user to get *better overview of student work*. With discovering plagiates the user can then determine why plagiarism has occurred in the first place and it can help him prevent this from happening in *future courses*.

Key words:

plagiarism, visualisation, Moss, Twitter, Facebook, Google

Chapter 1

Introduction

Every teacher struggles with the question, whether the work of a student is his own work or is it a plagiate. With the rise of computer era and World Wide Web, plagiarism has become more attractive. Students can now interact with their classmates easier than in the past. They are likely to connect together and form groups, as new ways of communications are available [1]. With increasing growth of plagiarism, new methods to discover plagiarism must be presented. But what methods could be used and in what way can they help teachers? There are many methods, some are adequate for this matter and some are not. But first, some terms should be described. Plagiarism, looked at a wider angle, can be classified in different ways [2].

One way of classifying plagiarism is according to the *source of plagiarism*. The process begins with a student being given an assignment. The work he later submits is called *student submission*. The set, which contains all student submissions for a given assignment is called *corpus*.

Plagiarism within that corpus is called *intra-corpal plagiarism*. This means that the source of plagiarism was within that corpus. Either one submission is connected to another submission, or more submissions were connected to each other. This group of connected submissions is then called *cluster*. Which submission was source and which was copied is not evident at the beginning, but it could be determined later in the stage of investigation.

If the source of plagiarism is outside of the corpus, this is then called *extra-corpal plagiarism*. Sources can be books, articles, solutions from other institutions and particularly World Wide Web which is becoming more and more appealing due to its simplicity to search required information. When two or more students copy from the same source outside the corpus, this can also appear as students copying from themselves, so the investigator must be aware of this.

Another way of classifying plagiarism is according to the type of material being examined. *Source code* submissions refer to computer code written in different languages (PHP, Java, C#,...). *Free text* submissions refer to texts, essays, theses, articles, etc. written in natural language such as English.

This diploma thesis is dealing with easing the investigation of intra-corpal source code plagiarism. Although investigating extra-corpal plagiairsm as well as investigating free text plagiarism could also be integrated in this project. What words detecting, investigating and others mean in relation to plagiarism, is revealed in the next chapter.

1.1 Four-Stage Plagiarism Detection Process

Figure 1.1 shows the Four-Stage Plagiarism Detection Process which was defined by Culwin and Lancaster [3]. Some stages in this process can be fully automated and some can be automated just in parts. Stages where computer icon is present can be automated by computer. Stages where person icon is present must have human assistance as well. If both are present, both computer and human assistance are needed.

First stage is called *collection*, where students submit their work. Second stage is called *analysis*, where the corpus of submissions is run through a *similarity engine*. This similarity engine produces an output where potentially plagiarised submissions are shown. Similarity between them is shown with *specific measure*. The effectiveness of the detection depends on similarity engine. There are many similarity engines available for use [4]. Similarity

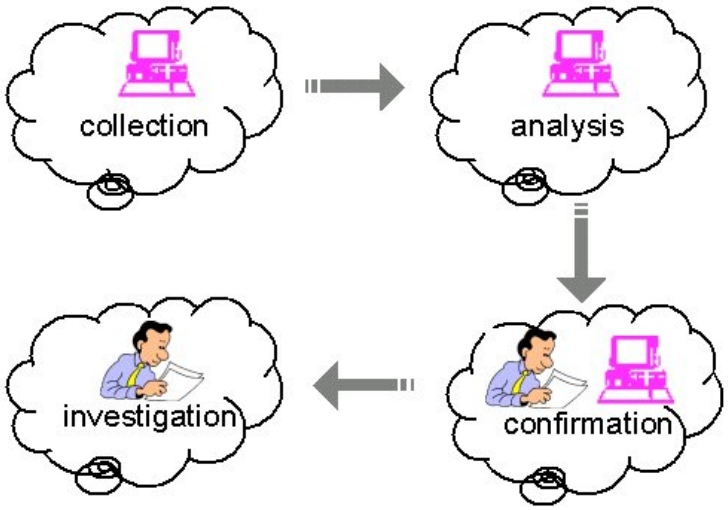


Figure 1.1: Four-Stage Plagiarism Detection Process

is just a score, shown in a defined measure, but does not yet indicate a plagiate. For a submission to become a plagiate, confirmation stage must be completed, where the submission is *examined* and *verified*. Therefore these two terms must be distinguished. The third stage is the stage of confirmation which is done by human. This stage is necessary to decide whether the reported similarity represents plagiarism or not. It can also be automated, but false positive and false negative results might occur. Any similarity which is confirmed as positive is then considered further in the investigation stage.

1.2 Diploma Thesis Overview

This diploma thesis addresses the following questions:

- What methods can assist in plagiarism detection process?
- Can social media sites and web search engines provide valuable information in plagiarism detection process?
- Can plagiarism be visualized and how can this help retrieving new information?
- What methods can be developed in future to help detect plagiarism?

This diploma thesis is organized as follows: Chapter 2 presents an overview of existing solutions. Revealing their disadvantages shows why this work can be used in detecting plagiarism. Chapter 3 focuses on technologies and tools that are essential for this program to work. Chapter 4 reveals how the application is composed and how each component works. It also describes the application functionalities. Chapter 5 sums up all the problems which were encountered during the application development. It also covers further work possibilities.

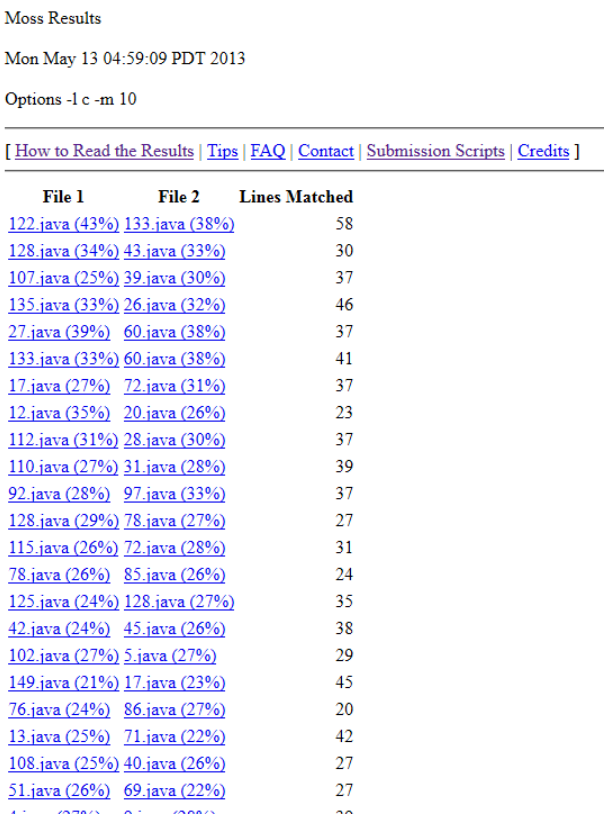
Chapter 2

Related Work

2.1 Review of Related Approaches

There are many tools for plagiarism detection available. One of the most popular are Sherlock [5], JPlag [6] and Moss [7]. Their basic functionality is very simple. Selected submissions are run through similarity engine which provides results with potential plagiates. JPlag and Moss do not have many other parameters to be changed.

One of the options in Moss is that user can set which *programming language* will be in corpus (Moss also automatically detects which language is used). Another option is to set *how many results are shown* (by default this value is 250, which is more than enough, but it can be reduced or increased). It also has option to select *base file*. When instructor gives assignment instructions, he can also provide some algorithms that can be used in that assignment. If user sets this algorithm as base file, the code that is included in that base file is ignored in every submission. Moss can also automatically detect these patterns even though they are not specifically added as base file. Yet another option is the option to set *maximum number of times a given passage may appear before it is ignored*. It is actually used to control Moss's sensitivity. If this number is N, then part of code must be present in N submissions to be ignored. So the bigger the N, more rigorous is the



Moss Results

Mon May 13 04:59:09 PDT 2013

Options -l c -m 10

[How to Read the Results | Tips | FAQ | Contact | Submission Scripts | Credits]

File 1	File 2	Lines Matched
122.java (43%)	133.java (38%)	58
128.java (34%)	43.java (33%)	30
107.java (25%)	39.java (30%)	37
135.java (33%)	26.java (32%)	46
27.java (39%)	60.java (38%)	37
133.java (33%)	60.java (38%)	41
17.java (27%)	72.java (31%)	37
12.java (35%)	20.java (26%)	23
112.java (31%)	28.java (30%)	37
110.java (27%)	31.java (28%)	39
92.java (28%)	97.java (33%)	37
128.java (29%)	78.java (27%)	27
115.java (26%)	72.java (28%)	31
78.java (26%)	85.java (26%)	24
125.java (24%)	128.java (27%)	35
42.java (24%)	45.java (26%)	38
102.java (27%)	5.java (27%)	29
149.java (21%)	17.java (23%)	45
76.java (24%)	86.java (27%)	20
13.java (25%)	71.java (22%)	42
108.java (25%)	40.java (26%)	27
51.java (26%)	69.java (22%)	27

Figure 2.1: Example of Moss results

similarity engine. With smaller N, many code parts are ignored and thus not shown as a match. When submissions are sent, the user receives an URL in which comparison data (*output*) is shown. Output is practically a list of matches (i.e. *one submission was detected to be similar to another one*), with percent of similarity and link to show where code similarity was detected. Example output is shown in Figure 2.1 and Figure 2.2. Moss can analyze code written in many languages. These are C, C++, Java, C#, Python, Visual Basic, JavaScript, Pascal, Perl and many others. A disadvantage of Moss is that submission script is currently available only for Linux. That being mentioned, every setting is set through attributes when starting script in shell.

JPlag is a Java based system that works like Moss. User sends submissions

Figure 2.2: Example of comparison between two submissions in Moss

to be checked. There are practically no extra settings in JPlag. Output with comparison data is similar to Moss and is shown in Figure 2.3, which was taken from a website that demonstrates how JPlag tool is used [8]. JPlag currently supports Java, C#, C, C++, Scheme and in contrast to Moss it also supports free text submission comparison. Both Moss and JPlag have HTML output, which means results can easily be parsed and stored in other formats to be used for other purposes. What JPlag and Moss do not offer is an option to create a list of matches where plagiarism is believed to be true. With that option, investigator (i.e. *the person who checks for plagiarism*) could easily go through desired matches and create a list of persons for further investigation. This feature however is available in Sherlock. Sherlock also has the feature to visualize matches and show them by clusters. But its visualisation system is obsolete and does not help much with investigation. That being said, Sherlock covers much more functionalities than Moss and JPlag, but output generated by similarity engine cannot be directly exported to other formats. Examples of Sherlock output are shown in Figure 2.4, Figure 2.5 and Figure 2.6 which were taken from a website that demonstrates how Sherlock tool is used [9]. Sherlock is in comparison to JPlag and Moss harder to install and regular user can have many problems initializing it.

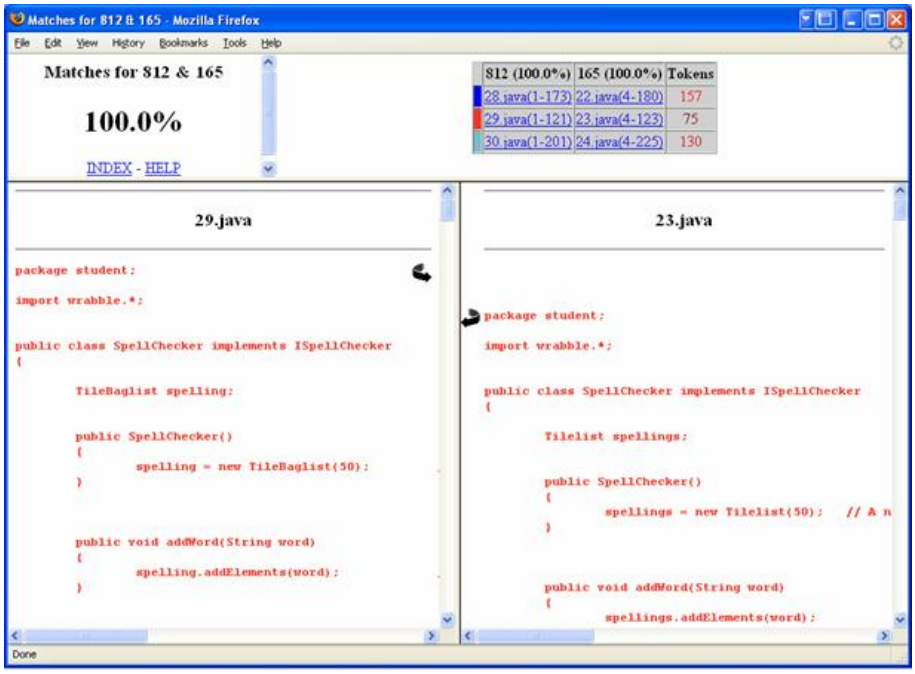


Figure 2.3: Example of comparison between two submissions in JPlag

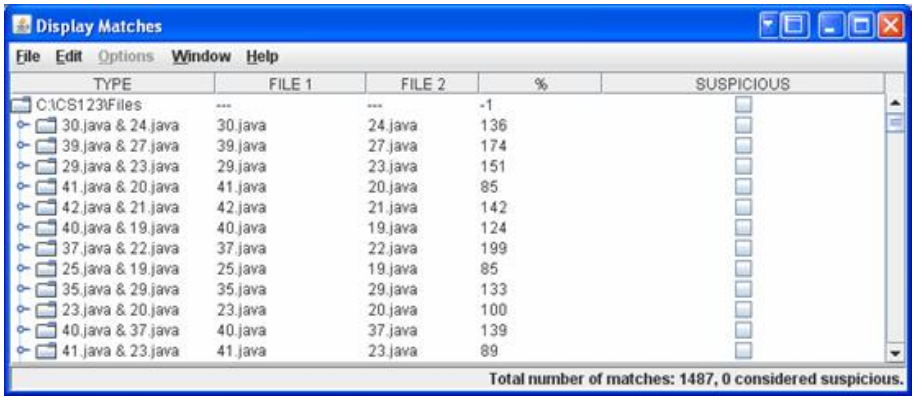


Figure 2.4: Example of Sherlock results

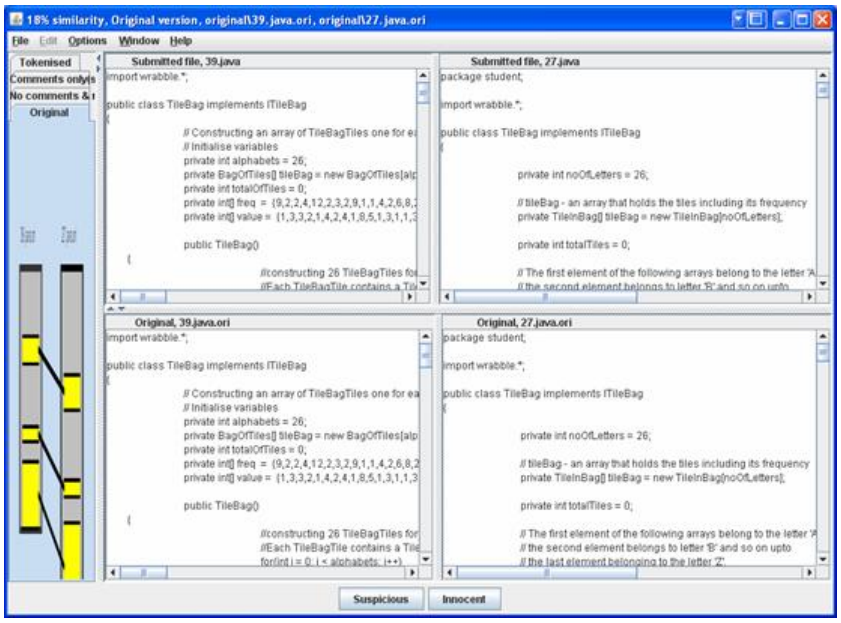


Figure 2.5: Comparison between two submissions in Sherlock

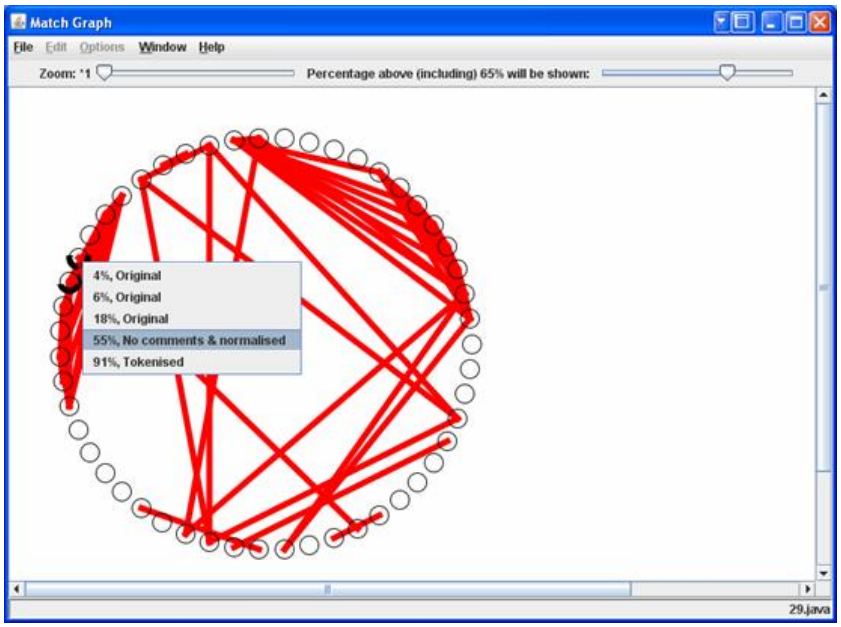


Figure 2.6: Example of visualizing matches in Sherlock

2.2 Proposal for Solution

In contrast to these available tools, the purpose of this work was to create a prototype application which provides the investigator new visualisation techniques and other methods to assist plagiarism detection. Sherlock does not support more than one assignment (corpus) to be available for investigation. This prototype can visualize more corpora (plural of *corpus*), which enables investigator to have an overview of student plagiarism through entire module (class). Different types of visualisations are also available in this prototype. Investigator can select suspicious matches and create a list which can be later further investigated. This functionality is also covered in Sherlock, but again it cannot be used for more assignments. This prototype also connects to social media websites, such as Facebook and Twitter, and looks for friendship relations between students. This gives important information in investigating plagiarism. It also checks name correlations on Google search engine. In the end, when matches have been investigated, report can be generated and printed. Investigator can then invite selected students for an interview, where they are evaluated whether they have plagiarised or not.

What would be the penalties for confirmed plagiates is not important in this case. What is important is the fact that investigator could receive an information why the plagiarism occurred in the first place. With that in mind he can prevent this from happening in future courses. By this, the teacher can provide students with the *proper mindset* not to plagiarise. If students continue with the old mindset and continue with plagiarism, this can also lead to violations of work place policies in the future, when they are employed [10].

In general, this prototype shows examples of how elementary functionalities make plagiarism detection tool more useful. Simple visualisations, connecting with World Wide Web, easy graphical user interface and other methods, which are described in later chapters, can simplify work for investigator.

Chapter 3

Used Technologies

The prototype application, created in this diploma thesis, uses different technologies. How this technologies and application are connected is shown in Figure 3.1. Basic functionalities in the application require Apache Web Server, PHP, MySQL Database and Local Storage to work. Web template is embedded in the application, so it is required as well. Because no similarity engine was developed in this application, it needs to connect to a provider from outside (in this case, *Moss*). These are the basic technologies that are needed. User can view different matches and users and also confirm and reject matches. Whether the user wishes to see visualisations, D3.js library is needed. If user wishes to connect to social media websites such as Facebook and Twitter, or check name correlations on Google, these technologies need to be available as well. Whether the user wishes to create a report, FPDF is needed. To include visualisations in this report, the application called Wkhtmltopdf is needed.

Each mentioned technology is described in further sections. Local storage is excluded, as it is not a technology but is *a priori* available on this application location. Why local storage is needed is explained in Chapter 4.1.

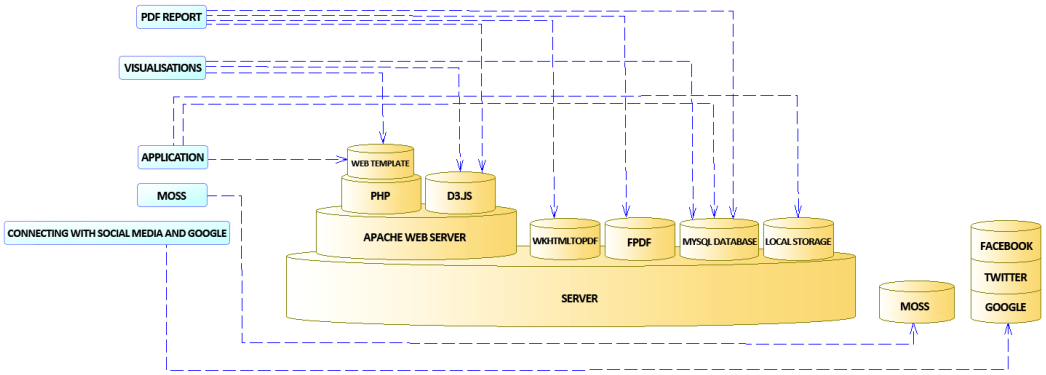


Figure 3.1: Architecture diagram of the application

3.1 PHP

PHP [11] is a very popular scripting language. It is especially suited for *Web development*. This language was created to generate *dynamic output* on websites (output that can be different each time a browser requests a page). PHP documents generally end with extension *.php* and can be embedded into HTML. This application has been developed in PHP language and that is why this technology is needed.

3.2 MySQL

MySQL [12] is one of the most popular database management systems (*DBMS*) for web servers. It was developed in mid-1990s and the fact that it has become so popular and wide-spread is because it is *free to use*, like PHP. MySQL implements relation database and uses SQL, which means *Structured Query Language*. With SQL queries, data can be retrieved from database.

MySQL database contains one or more tables called *entities*. Each table has one or more columns called *attributes*. It also has one or more rows. Each row represents one entry in that table. Attributes define properties of that entity. Each entity can be connected to one and more other entities. With

such specifications, database is created. Database server can contain multiple databases. The application that was developed in this diploma thesis uses MySQL database to store almost all data that it uses.

3.3 Apache Web Server

The Apache Web Server [13] is an open-source HTTP server. It can operate on many operating systems including UNIX, Microsoft Windows, Mac OS/X and Netware. Apache has been one of the most popular web servers since year 1996. It supports integration with PHP and many other scripting languages. It is required for this application to work, because the application is web-based.

3.4 D3.js

3.4.1 Introduction

D3 is a *JavaScript library* which manipulates documents based on given data. D3 connects elements such as HTML, CSS and SVG. It was created as a successor to a similar tool called Protovis, which was also intended to create simple and more complex visualisations.

The D3 library can be downloaded from `http://d3js.org`. Example of how D3 library can be used is shown in Code 3.1 [14].

```
<!DOCTYPE html>
<html>
<head>
  <meta charset="utf-8">
  <script src="d3.js"></script> ❶
  <script>
    function visualisation(data) { ❷
      // To the given data, visualisation is created
    }
  </script>
</head>
<body>
  <script>
    d3.json("data.json", visualisation); ❸
  </script>
</body>
</html>
```

Code 3.1: Example of D3 library usage as shown in Mike Dewar's Getting Started with D3

❶ Include D3 library in web page to give access to D3 methods.

❷ Example of one-argument function, which is called when data is loaded at step 3.

❸ Load JSON data from file data.json and call function visualisation - data is passed as an argument.

Data that is used with D3 library is stored in JSON format. Other formats, such as XML and CSV, could also be used, but in this case JSON structure is used. Example of data.json file is shown in Code 3.2. It has one attribute called *nodeSet*. It is an array and has two entries. Each entry has five more attributes named *id*, *name*, *group*, *hlink* and *count* and they all have some assigned value. For example the first entry has attribute "id" with value "1". This example is also used in visualisations and is described in Chapter 4.5.

```
{
        "nodeSet" = [
                {
                        "id": "1",
                        "name": "10090101",
                        "group": "0",
                        "hlink": "?view_p=1",
                        "count": "2"
                },
                {
                        "id": "2",
                        "name": "10090105",
                        "group": "0",
                        "hlink": "?view_p=2",
                        "count": "2"
                }
        ];
}
```

Code 3.2: Example of JSON data file

3.4.2 Force-Directed Graph

Force-Directed Graph that is used to visualize plagiarism uses *force layout* [15], which enables nodes and links to be appropriately distributed in a canvas. Example of how Force-Directed Graph can be visualized with D3 is shown in Figure 3.2. For visualisation of plagiarism, a template from site "bl.ocks.org" by Mike Bostock was used and modified for appropriate needs [16].

Figure 3.2: Example of Force-Directed Graph visualisation

3.4.3 Co-Occurrence Matrix

Example of how Co-Occurrence Matrix looks like when visualizing it with D3 library is shown in Figure 3.3. For visualisation of plagiarism, a template from site "bost.ocks.org" by Mike Bostock was used and modified for appropriate needs [17].

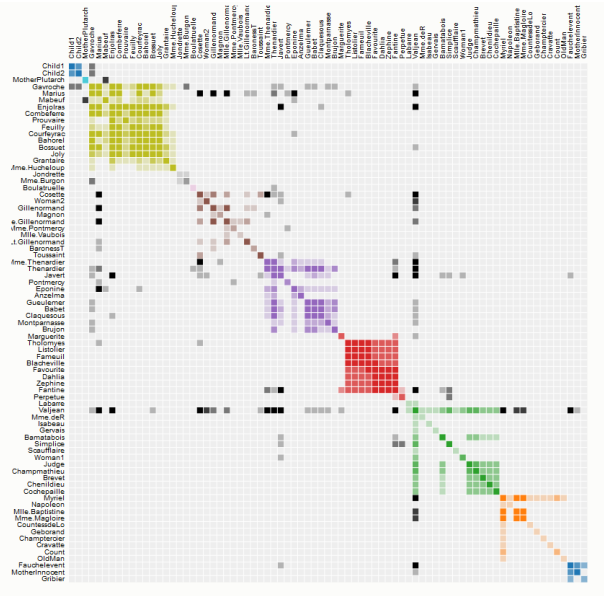


Figure 3.3: Example of Co-Occurrence Matrix visualisation

3.5 FPDF

To generate a report, FPDF was used. FPDF is a PHP class, which generates PDF files. It can be retrieved from `http://www.fpdf.org`.

3.6 Wkhtmltopdf

Wkhtmltopdf is software used to generate PDF files from HTML. When generating report, pictures of visualisation are also shown. D3 is a JavaScript based library, which means that the code to generate visualisation is run on the client side. To save generated visualisation, some interface must be available, which can act as a client. Wkhtmltopdf is used to create *snapshots* of this visualisations so that they can later be integrated in report.

If application is run on a Linux based system that supports aptitude, next commands should be executed.

```
sudo apt-get install xinit ❶
sudo apt-get install xvfb ❷
sudo apt-get install wkhtmltopdf ❸
```

❶ Xinit is needed to install everything necessary for X Windows System to work.
❷ Xvfb is X11 server, that can perform graphical operations, without showing any screen output.
❸ Wkhtmltopdf is the previously described application.

To start Wkhtmltopdf in a shell it must be run through Xvfb. Script to start Wkhtmltopdf through Xvfb is already included in this application in file *wkhtmltopdf.sh*. Contents of this file are as follows:

```
xvfb-run -a -s "-screen 0 640x480x16" wkhtmltopdf $*r
```

If aptitude is not available, following installation guide is available at `http://code.google.com/p/wkhtmltopdf/wiki/compilation`. Note that Wkhtmltopdf must be accessible to wkhtmltopdf.sh if visualisations are to

be integrated in the report. If this application is not available, option to show visualisations in the report will be *disabled*.

3.7 Website Template

To make website look more user friendly, a web template was needed. Web template Charisma, created by Muhammad Usman was used [18]. It is licensed under Apache License, Version 2.0 [19]. It had all necessary features, had clean look and was free to use, modify and publish.

3.8 Moss

Moss (*Measure Of Software Similarity*) is a system for detecting software plagiarism. As it was mentioned before, this is so-called similarity engine. Moss was developed in 1994 and is very effective in this role. Moss service is provided through Internet. Moss functionalities are described in Chapter 2.1. If user wishes to use Moss, an account must be created. This can be done by sending the following email to *moss@moss.stanford.edu*.

```
registeruser
mail username@mail
```

Note that email address in italics is user's email address. User then receives ID, which is used to authenticate queries to the server. Without this ID, Moss does not work. More on how Moss similarity engine works can be read in *Winnowing: Local Algorithms for Document Fingerprinting* [20].

3.9 Facebook API

Facebook created special API (*Application programming interface*), so that developers can create applications which are connected with Facebook. For this work only queries on Facebook database are executed, so the application development changed it's original meaning. But in order to make queries, application on Facebook needs to be created.

1. First step is to create Facebook account. If the investigator who uses this application, has no account yet, one should be created. Note that multiple and fake Facebook accounts are *prohibited*.

2. Next step is to create Facebook application. This is done at the following page: `https://developers.facebook.com/apps`. To create a new application, click button "Create New App".

3. Enter name of application, then enter address where this application is hosted. Address should be entered in sections "Website with Facebook Login" and "App on Facebook".

4. Then save changes and go to "Use Graph API Explorer". User access token is generated, and this access token is then used when making queries on Facebook.

Now that user access token is available, some specific characteristics of the token must be changed. This is due to the fact that user access token can become expired. This can happen because of *four different reasons*:

1. The token expires after *expiration time*, which is set to 2 hours by default.

2. The token expires if user *changes his password*.

3. The token expires if user *de-authorizes application*.

4. The token expires if user *logs out of Facebook*.

The second and third reason do not present a problem, but first and the last do. So next thing to do is to make token valid, even if user logs out. This means that it is available in *off-line mode*. Also expiry time must be extended. Maximal expiration time is currently 60 days, so this option is used. This can be achieved by visiting next URL. Note that *APP_ID*, *APP_SECRET* and *EXISTING_USER_ACCESS_TOKEN* must be changed with appropriate values.

```
https://graph.facebook.com/oauth/access_token?
    client_id=APP_ID
    &client_secret=APP_SECRET
    &grant_type=fb_exchange_token
    &fb_exchange_token=EXISTING_USER_ACCESS_TOKEN
```

New access token is generated and it is shown in output. Now that user access token is available in off-line mode and will not expire for next 60 days, it can be used to get the required data.

To make queries on Facebook with PHP code, *cURL* is used. cURL (*libcurl in PHP*) is a library created by Daniel Stenberg and is already integrated in PHP. It allows user to connect and communicate with servers using protocols such as HTTP, HTTPS, FTP and others. Simple example of how HTTP request is sent with cURL is shown in Code 3.3.

```
<?php
function retrieveData($url){
        $ch = curl_init();❶
        curl_setopt_array($ch, array(❷
                CURLOPT_URL => $url,
                CURLOPT_RETURNTRANSFER => true
        ));
        $result = curl_exec($ch);❸
        curl_close($ch);❹
        return $result;❺
}
?>
```

Code 3.3: Example of how cURL is used in PHP

❶ Initialize a cURL session.

❷ Set multiple options for cURL. In this case URL is defined. This is URL where request is sent. Second parameter is enabled so that cURL returns a string of answer, not just the value true or false. Other options could be also added such as adding headers, port, SSL, user agent and many more, which are not needed in this case.

❸ Perform a cURL session.

❹ Close a cURL session.

❺ Return results (e.g. *HTML page or JSON file*).

Facebook API has different options of how to make queries. The simplest way is to use cURL and pass the appropriate URL. The following example shows how to search for users, when user access token and search query parameters are given. Note that even though some data is not hidden on Facebook, one still requires *user access token* to have access to it. Results from Facebook are returned in JSON format, which was previously described in Code 3.2. Example with connecting to Facebook is shown in Code 3.4.

```
<?php
function getUsers($search_query, $fb_access_token){
        $url = "https://graph.facebook.com/search?access_token=".
            $fb_access_token."&q=".urlencode($search_query)."&type=user";❶
        $ret_json = retrieveData($url);❷
        $users = json_decode($ret_json, true);❸
        return $users;❹
}
?>
```

Code 3.4: Example of how connection to Facebook is made

❶ This is the format of URL that is needed to retrieve results. User access token must be given, because it searches for users. If the type was a page and not a user, then application access token could be used as well. Search query is the string for searching users, "Jack Smith" for example.
❷ Function which was presented in Code 3.3 is called with defined URL address.
❸ Results are decoded with function json_decode, which is integrated in PHP. It takes JSON encoded result and converts it to a PHP variable.
❹ Function then returns every matching user in an array.

The array which is being returned by function shown in Code 3.4 has specific structure. Example of returned JSON is shown in Code 3.5.

```
{
   "data": [
      {
         "name": "John Doe",
         "id": "100000000000001"
      },
      {
         "name": "Jack Smith",
         "id": "100000000000002"
      }
                ],
   "paging": {
      "next": "<deleted, as it is not important for this matter>"
   }
}
```

Code 3.5: Example of Facebook user search JSON output

The procedure is the same when retrieving user data. For this matter, data that shows whether two users are friends must be retrieved. This is done in example shown in Code 3.6.

```
<?php
function retrieveFriends($fb_user_id, $fb_access_token, $fb_friend_id){
        $url = "https://graph.facebook.com/".$fb_user_id."?fields=friends.
            uid(.$fb_friend_id)&access_token=".$fb_access_token;❶
        $ret_json = retrieveData($url);
        $friends = json_decode($ret_json, true);
        return $friends;
}
?>
```

Code 3.6: Example of how to retrieve a result that shows whether two users are friends

❶ This is the format of URL that is needed to retrieve whether selected user is friend with other Facebook user.

The array which is being returned by function shown in Code 3.6 has specific structure. Example of returned JSON is shown in Code 3.7. If there is friendship correlation, results in friends section will be shown. If there is no connection between selected users, data section would be *empty*. In this case user

with ID "100000000000001" is friend with user with ID "100000000000002".

```
{
   "id": "100000000000001",
   "friends": {
      "data": [
         {
            "name": "Jack Smith",
            "id": "100000000000002"
         }
      ],
      "paging": {
        "next": "Deleted, as it is not important for this matter."
      }
    }
}
```

Code 3.7: Example of Facebook friend relationship JSON output

This solution is not the best, as many requests are sent. Every user in database must be checked with other users (*if they are under suspicion for plagiarism*). Unfortunately there is no option to retrieve a specific user friends list, unless this user is using a created application. If that was possible, then this list would be retrieved and stored locally. Then it would also be checked for friendship relationships locally. That would reduce a great deal of number of queries. But even though user has a public friends list, this is not possible due to Facebook APIs restrictions. It is only possible to check if a specific user is friend of that user (*if that user has public friends list*). If two users are friends on Facebook, this can be obtained from the data in returned array.

There is one thing that has to be taken into account and that is that Facebook API has limits other than mentioned at the beginning. There is a limit on number of queries that one user can make. This limit is 600 queries per 600 seconds (per one token and one IP). When this limit is reached, new queries will be *denied*. This could be bypassed by connecting to Facebook as user and then parsing data from Web. But this solution is not good as Facebook changes design very often and algorithms would need to be adapted and changed as they would not work anymore.

These are the basics that are used in application. More on Facebook API can be read at `http://developers.facebook.com/docs/reference/api`.

3.10 Twitter API

Twitter has it's own API like Facebook. The procedure to make queries is almost identical as with Facebook. First application needs to be created to retrieve the needed keys. With that keys user authorizes himself and then queries can be made.

1. First step is to create Twitter account. If the investigator who uses this application does not have account yet, one should be created.

2. Next step is to create Twitter application. This is done at the following page: `https://dev.twitter.com/apps`. To create a new application, click button "Create a new application".

3. Enter name of the application, description of application and then enter address where this application is hosted.

4. Then save changes and go to "Create my access token" in application settings. OAuth access token is generated, and this access token is then used when making queries on Twitter.

Now that access token (along with access token secret, consumer key and consumer secret) is available, queries are ready to be executed. In contrast to Facebook tokens, Twitter token does not expire. However to access to Twitter API, *OAuth is required*. OAuth is an authentication protocol which enables users to have access to Twitter API without sharing their password. In this application, special OAuth library is used. It is called Twitter OAuth and was created by Abraham Williams [21]. It is specifically created to connect with Twitter API. Example of retrieving users is shown in Code 3.8.

```
<?php
function getUsers($search_query, $consumer_key, $consumer_secret,
    $access_token, $access_token_secret){
        require_once('twitteroauth.php');❶
        $connection = new TwitterOAuth($consumer_key, $consumer_secret,
            $access_token, $access_token_secret);❷
        $ret_json = $connection->get('https://api.twitter.com/1/users/search
            .json?q='.urlencode($search_query));❸
        $users = json_decode(json_encode($ret_json), true);❹
        return $users;❺
}
?>
```

Code 3.8: Example of how connection to Twitter is made

❶ Twitter OAuth library is loaded into script.

❷ New Twitter OAuth instance is created with corresponding keys and tokens.

❸ Connection to Twitter is made through Twitter OAuth library. URL, similar to the one in Facebook, is passed with search query.

❹ Results are decoded with function json_decode, which is integrated in PHP. It takes JSON encoded result and converts it to a PHP variable.

❺ The function then returns every matching user in an array.

Example of structure of returned array is shown in Code 3.9. Note that not all data is shown as it is not required for this case.

```
{
   {
      "id" : 100000001,
      "name" : "John Doe",
      "screen_name" : "JohnDoe1",
   },
   {
      "id" : 100000002,
      "name" : "Jack Smith",
      "screen_name" : "JSmith",
   }
}
```

Code 3.9: Example of Twitter search JSON output

When user wants to retrieve friendship data, this is similar to Facebook API. The procedure is exactly the same as it is in Code 3.8, only the URL is different. Line which is different as in Code 3.8 is shown below.

```
$ret_json = $connection->get('https://api.twitter.com/1/
    friendships/show.json?source_id='.$source_id.'&target_id='.
    $target_id);
```

Whether two users are following each other on Twitter, this can be obtained from the data in returned array. Example of structure of returned array is shown in Code 3.10. Note that not all data is shown as it is not required for this case. In this example user with ID "100000001" follows user "100000002" but not the other way around.

```
{
   "relationship" : {
      "source" : {
         "followed_by" : false,
         "following" : true,
         "id" : 100000001,
         "screen_name" : "JohnDoe1",
      },
      "target" : {
         "followed_by" : true,
         "following" : false,
         "id" : 100000002,
         "screen_name" : "JSmith"
      }
   }
}
```

Code 3.10: Example of Twitter friendship JSON output

Note that Twitter API also has limitations on how many queries can be made. This limit is 150 queries per hour. When this number is reached new queries will be *denied*. Note that this can also be bypassed like with Facebook, but it would probably not work for long. This is due to the fact that developers on Twitter continuously change site appearance and parsing data from website would work only until the page is not changed. Then the algorithm would have to be changed.

These are the basics that are used in application. More on Twitter API can be read at `https://dev.twitter.com/docs/api`.

3.11 Google API

Connecting with Google API is very similar to Facebook and Twitter API. The difference is only that user does not have to have an account or application created to use API. But what user does need to provide is his IP and referer IP address. Example of how to get results for a search query on Google API is shown in Code 3.11. This example returns number of results. Other data can also be retrieved and this data is presented as shown in Code 3.12.

```
<?php
function getNumberOfResults($search_query){
        $url = 'https://ajax.googleapis.com/ajax/services/search/web?v=1.0&q
            ='.$search_query.'&userip='.$_SERVER['REMOTE_ADDR'];❶
        $ch = curl_init();
        curl_setopt($ch, CURLOPT_URL, $url);
        curl_setopt($ch, CURLOPT_REFERER, $_SERVER['SERVER_NAME']);❷
        curl_setopt($ch, CURLOPT_RETURNTRANSFER, true);
        $result_html = curl_exec($ch);
        $result_json = json_decode($result_html, true);
        curlclose($ch);
        return $result_json[responseData][cursor][estimatedResultCount];❸
}
?>
```

Code 3.11: Example of how connection to Google is made

❶ URL required to get results from Google. Search query and user IP address are passed as arguments.

❷ Among other parameters, IP address of server hosting application is passed.

❸ Number of estimated results count is returned.

```
{ "responseData" : { "cursor" : { "currentPageIndex" : 0,
          "estimatedResultCount" : "625000000",
          "moreResultsUrl" : "http://www.google.com/search?oe=utf8&ie=utf8&
              source=uds&start=0&hl=en&q=google",
          "resultCount" : "625,000,000",
          "searchResultTime" : "0.11"
        },
      "results" : [
        ]
    },
  "responseDetails" : null,
  "responseStatus" : 200
}
```

Code 3.12: Example of Google search JSON output

Google Search API also has limitations which are far more strict as they are on Facebook and Twitter. Limit is currently 100 searches per day. If user wishes to bypass this like with Facebook or Twitter - by presenting it's application as normal user agent like Firefox or Chrome, this would not work. First results would be a success and parsing data out of results is not complicated. But Google then realizes that this so-called user might be robot (*application in this case*) and asks for Captcha code to determine whether you are a real person. This happens because normal user never tries to make so many queries in such a short time. Solution to this problem is to buy more searches per day, but 5$ per 1000 queries (that is the price they charge you) is not worthy for this matter. This are the basics that are used in application. More on Google Search API can be read at `https://developers.google.com/custom-search/v1/overview`.

Chapter 4

Implementation of PDA

Application called Plagiarism Detection Assistant (or *PDA*) has multiple functionalities available. Example of which functionalities a user can use is shown in Figure 4.1. All functionalities shown in that figure are implemented in this application, but names may be different compared to those in application. Functionalities shown on the right side of diagram are also implemented in this application but they need outside resources (*moss.stanford.edu*, *Facebook*, *Twitter* and *Google*) to work and cannot work without them. This chapter explains how this functionalities are implemented and how they work.

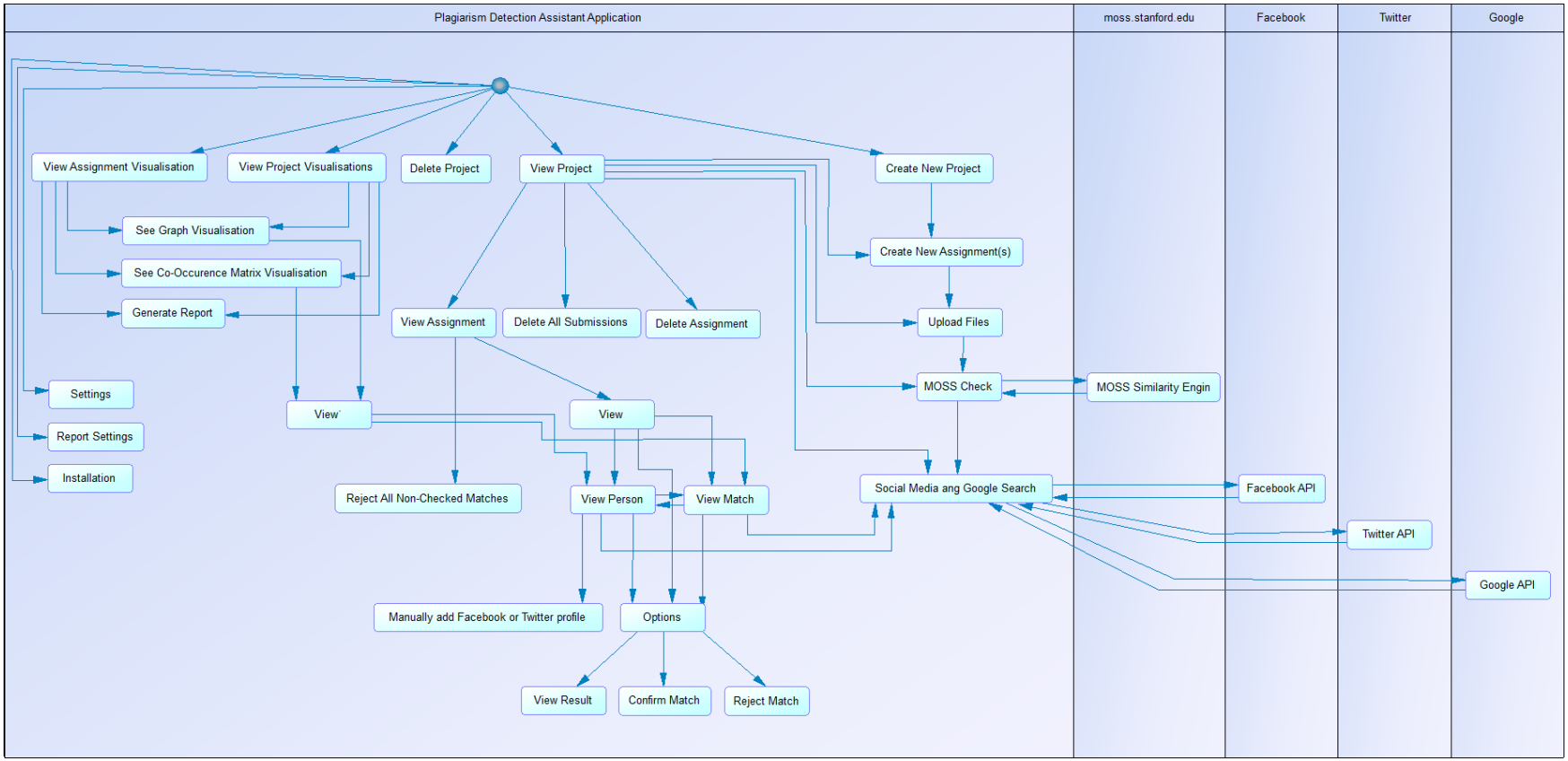


Figure 4.1: Functionalities diagram of application

4.1 Database

This diploma thesis application needs *database* to have different data stored. Which data is stored in MySQL database and which is stored locally is presented in this chapter.

The data which is essential for this application to work is stored in MySQL database as it is the most appropriate form of storing data. Figure 4.2 shows physical diagram of database used in this application. Application is designed so that investigator (later referenced as *user of the application*) creates new project which is practically a class or module in school/university. Each class consists of one or more assignments. And each assignment has one or more submissions. Database is structured on the same form.

At the top of Figure 4.2 there is an entity called "project". Each instance of this entity has it's own unique ID which is also primary key. It also has project name and project status. What the project status represents in this case is whether this project is enabled or deleted. Every data, even if deleted in application, still exists in database, but it is disabled. This means it will not be shown and will not be available to user (*it will look as if it is deleted*). If project status is set to "1" it means it is enabled, if it is set to "2" it means it is deleted. By default status is set to "1" when created.

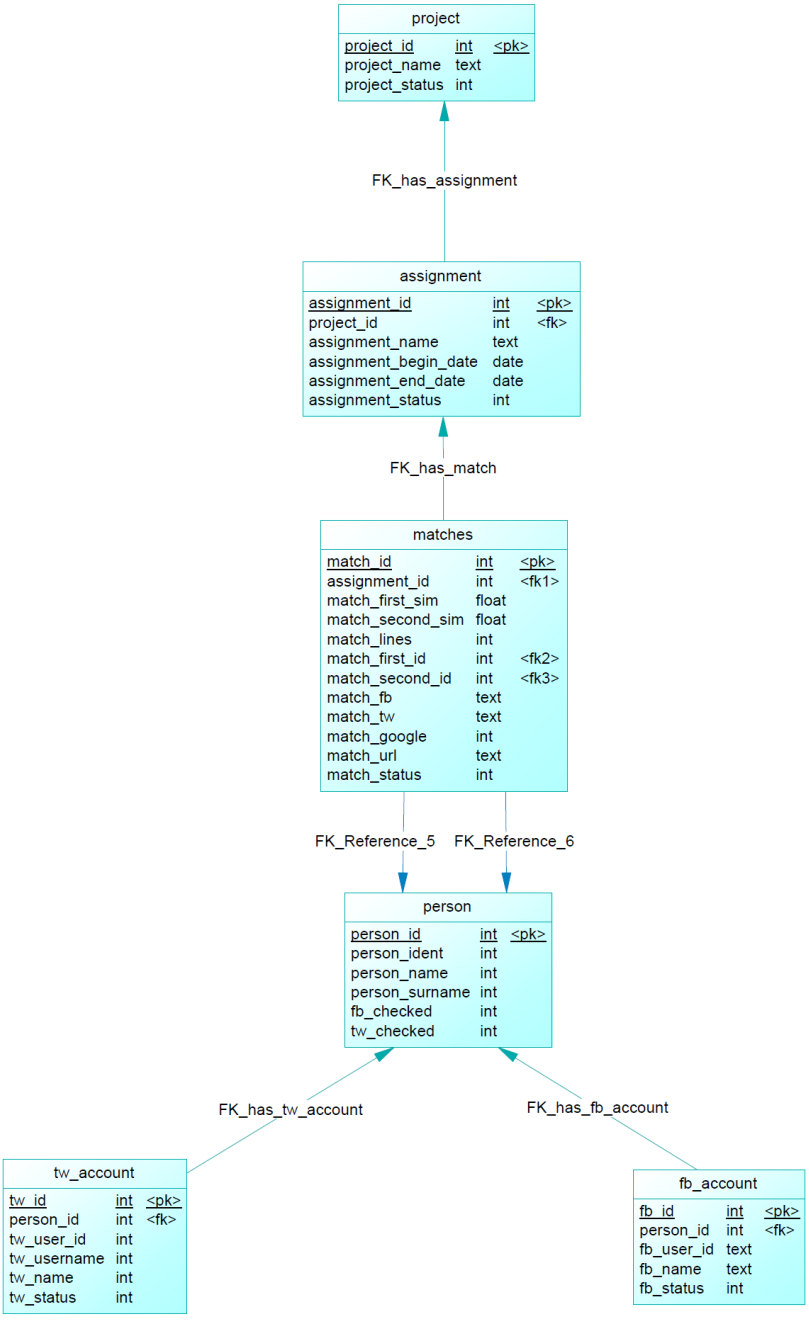


Figure 4.2: Physical diagram of used database

The next entity is called "assignment". Every project can have one or more assignments. Each instance of this entity has it's unique ID which is also primary key. It also has foreign key to entity project, so every assignment can be connected with the appropriate project. Assignment name is also stored, so that the user can distinguish between different assignments. Assignment begin date and end date are also available, but are currently not used in application. They are only there so when next version of application is released, it could support other functionalities in application which have not been implemented yet. Like with entity project, this entity also has it's status. Assignment status can have three different values. When new assignment is created it has assigned value "0". When submissions are run through similarity engine, assignment status changes to value "1". If there is a new submission uploaded to application, value changes to "0" again. If assignment is deleted (or project, which also includes this assignment), status changes to value "2".

The next entity is called "matches". When submissions are run through similarity engine, matches are returned. Each match includes data which student (*submission*) is included in that match and what is the similarity between these two submissions. Each instance of this entity has it's unique ID which is also primary key. It also has foreign key to be connected with it's assignment. In addition it also has two foreign keys which are referenced to persons (*students*). As mentioned before every match has two submissions connected. In this application new person is created for each submission. Submissions resulting from same person should have same file name in different assignments, so that person can be followed through assignments. Similarity between two submissions is also stored in this entity. Attribute "match_first_sim" represents similarity that occurs between the first and the second submission. Attribute "match_second_sim" represents similarity that occurs between the second and the first submission. Both are needed, because submissions are not of same length. The first submission can have 50% similarity for example, and at the same time the second submission can have

only 30% similarity related to the first submission. This is because there are number of lines which are detected similar and similarity is a relative number related to the length of file. Attribute "match_lines" is available so that number of similar lines is stored. Then there is an attribute called "match_fb". If there is a match found between two persons on Facebook it is stored in this attribute. Example of entry in this attribute is "id1&id2". In this case more Facebook matches are not needed because probability of more persons with specific name and surname having friendship relation on Facebook is very low. And for this case only information whether two persons *are friends on Facebook* is needed. When searching for friendship relations on Facebook, the algorithm stops after the first relation between two persons has been found due to limitation of queries. If necessary, new matches can be added, separated by comma or similar. If there is no relation found or if match has not yet been checked for Facebook relations this attribute is empty. The next attribute is "match_tw", which works in the same way as "match_fb". The only difference is that here the direction of friendship relation is also stored. It is stored as "id1&id2&relation_status", where relation status can have three different values. If relation status is "1", it means that the first person follows the second person. If relation status is "2" it means that the second person follows the first person. If relation status is "3" it means both persons follow each other. Attribute "match_google" stores the number of found results on Google. Search term on Google search query is in this case "Name1 Surname1"+"Name2 Surname2"+"keywords", where Name1 and Surname1 are the name and surname of the first person in match, and the same for the second person. Keywords are defined in settings menu and are not mandatory. By default value of this attribute is "-1", which means the search between selected persons was not yet started. If it is zero or greater this is then the result. Attribute "match_url" has url of the similarity engine match result. This file is stored locally (not in the database), because Moss deletes this data from their servers after specific time. So every result is downloaded and stored locally, and can be retrieved at any time. The last

attribute is status. Status of each match can have four possible values. If match is added in database it gets default value "0". If user confirms selected match as potential plagiate, it gets value "1". If it is rejected by user it gets value "2". If match is deleted (this happens when corresponding assignment or project is deleted), it gets value "3".

The next entity is called "person" and stores each individual person's data. Every instance of this entity has its own unique ID which is also primary key. If name of the submission is for example "Name_Surname_(person_id).java", name is stored in attribute "person_name", surname is stored in "person_surname" and person identification number is stored in "person_ident". Note that if person has two or more names or surnames this will all be stored in "person_surname". For example "Name Surname1 Surname2" would result in name being stored as name, and both surnames stored in the surname attribute. If only name and surname are provided (e.g. *Name_Surname.java*), identification number will be generated with the first number being project ID number, multiplied by 10000000 and added number of which person was added (zero, one, two,...). If only identification number is provided (e.g. *person_id.java*), name of the person will be the same as person ID, surname will be empty and person ID will be person ID. This entity also stores information whether Facebook or Twitter relations were checked for this user. If it were and results were found, this data is then stored in separated entity, because more results can be retrieved for each user. By default this value is "0" and means it was not checked. If it is "1" it means it was checked. If it is "2" on the other hand it means that this user has already been checked for Facebook accounts but relations check was not yet started.

The next entity is called "tw_account". Each instance of this entity has its own unique ID which is also primary key. It also has foreign key which refers to specific person. Twitter user ID is stored as well as it's full name (*tw_name*) and so called Twitter name (*tw_username*), which is another option for ID. The same data is stored for Facebook in the entity called "fb_account",

except that Facebook name is not stored as it is not required. Both also have attribute called *fb_status* or *tw_status*. This attribute can have three values. If it is "0" it means it was added automatically when starting the search. If it is "1" it means it that user confirmed this account as correct one. If it is "2" it means it was deleted by user as it was not correct.

This is everything concerning the MySQL database, but this application also stores other data. This data is stored locally in map called "projects". Each project has subfolders of assignments with names of assignment IDs. Each assignment folder then has two more folders called "moss" and "submissions". In map "submissions" all submissions are stored. In map "moss", results of Moss are stored. If Moss was started multiple times, all results are stored, but only the latest are used. This happens when user adds submissions and starts Moss check. Then he can re-upload files, or upload new files and starts Moss check again. New results are stored locally and changed in database. Old matches are disabled. Old users stay in database. Note that when submissions are uploaded and Moss check is done, Moss check cannot be redone until after the change in submission area was made (new file uploaded, files deleted,...).

4.2 Use of Moss

When starting Moss check in this application, ID of the assignment is given to the function which starts Moss check. First Moss script is started. By default there are no special parameters given to the script. Script returns URL of the results and they are downloaded to the local folder. Because every result file was originally stored at Moss site (`http://moss.stanford.edu/results`), every file must be changed so it can be used locally. This is done by exchanging every link in results files with the appropriate one. After that, results need to be converted and stored in database. First thing that is done is that every match in database, which has the same assignment ID as the current one is changed to disabled. If there are no matches yet, nothing is done. But when there are (as described in the previous chapter, *when starting Moss check more than once*), they need to be disabled as new will be stored in database. Next assignment status is set to "1", which means it was checked with Moss. At that time Moss check button (for this assignment) disappears.

Results are then parsed with DOM (*Document Object Model*). First, persons are created in database. At the beginning, procedure checks whether user with the same user identification number already exists in the database and if not, new is created. If the person already exists this part is skipped. After two persons from match are added to database, new match is created. Every data that was retrieved from parsing is added. Note that file format must be as it was previously described (e.g. *Name_Surname_(ident).java*, *Name_Surname1_Surname2_(ident).java*, *Name_Surname.java*, *Name_Surname1_Surname2.java* or *ident.java*). Number of surnames is unlimited. Extension of file can be everything (*c, java, php, cpp,...*).

4.3 Social Media and Google Search

4.3.1 Facebook

Due to limitations regarding the number of permitted queries (as mentioned before, 600 queries per 600 seconds), functionality to check only first N matches was added. In settings menu user can select so called Social media start and end position, which specifies which matches will be checked. For instance if start position is set to "0" and end position is set to "9" only first ten matches will be checked for Facebook, Twitter or Google. This means that first ten matches will be checked. Note that if the tenth or greater match (ordered by "match_first_sim") has the same similarity as the ninth, this will also be used. How does this work: when user defines upper and lower limit at matches, this algorithm checks similarity at that match and when matches are checked with Social media and Google, they are limited by similarity; so not necessarily the first ten will be checked, but it can also happen that more will be checked. This functionality is added in this way because user has limitations on queries and if he wishes to check all of them he can easily check first ten matches, and then after six hundred seconds he can repeat the procedure for next ten matches. Option to check specific person or match is available as well.

At the beginning minimal and maximal allowed similarity is calculated according to given settings. Then each user from database that complies with limitations is selected. Note that one limitation is that match which is used in current assignment must not have attribute "match_status" set to three as this means it is disabled/deleted. Next users are searched like in Code 3.4. Search query is in this case "Name Surname" of each person. Facebook user search does not provide 100% accurate results so they need to be checked locally. This is done as follows. For every person two names are generated. First is "Name Surname" and second one is "Surname Name". For both names Levenshtein distance is calculated with each retrieved result [22]. If Levenshtein distance between the first generated name and retrieved name or

the second generated name and retrieved name is lower than 5, then this user is inserted into entity "fb_account". This means that the original name and the retrieved name can differ in maximum four characters. This is because some languages like Slovenian have letters like "č, š and ž" which are on Facebook stored as "c, s and z" and thus names can be different. Sometimes names are changed right for the reason that they do not wish to be found by search engines and this finds those users as well. Levenshtein distance being maximum at four was defined because this limit set too low would not solve this problem, and limit set too high would result in adding incorrect persons. Whether person was found on Facebook or not, person is marked as being checked on Facebook (attribute "fb_checked" in entity "person") so when investigating, this will show as if there was search performed and no results were found. Note that if Facebook account is added manually, this will be marked as being checked for accounts, but it still has to be checked (*or rechecked*) for relations.

When every user from these matches is searched on Facebook, friendship relations are searched. So what is done next is that every user combination (retrieved from selected matches) is searched on Facebook. If one user has more Facebook accounts, every account is checked with every other account. This occurs if there are more persons with specific name and surname on Facebook and algorithm does not know which one is correct. With algorithm shown in Code 3.6 friendship relations are checked. If there is a match, algorithm stops and stores data to entity "matches". Note that if this check is done after the person's Facebook account has been confirmed by investigator, only confirmed account will be checked when checking for relations.

4.3.2 Twitter

Twitter search works very similar to Facebook. There is also a limitation and procedure is the same as it is described in the previous chapter. The only difference is when storing data in database. Twitter namely has a direction of friendship. One user can follow another or the other way around and both users can also follow each other. When data is stored this information is also stored next to IDs that are connected. This is described in Chapter 4.1.

4.3.3 Google

Retrieving Google data also has limitations and these are the same as described previously. When searching for results four combinations are used:

- "Name1 Surname1" + "Name2 Surname2" + "keyword(s)"
- "Surname1 Name1" + "Name2 Surname2" + "keyword(s)"
- "Name1 Surname1" + "Surname2 Name2" + "keyword(s)"
- "Surname1 Name1" + "Surname2 Name2" + "keyword(s)"

Number of results for each search query is summarized and that value is returned. Results are retrieved like shown in Code 3.11. The estimated result number is returned and that value is summarized. Names are the names of persons in specific match. Keywords are stored in the settings menu. If there are no keywords given, they are not used in search. Multiple keywords are separated by comma. The reason why keywords are used is because some names can be very popular and number of results can be much greater than average. Another option would be to cut all deviated values but in this case, keywords are used to reduce the number of results. Keywords can be name of the university or name of city and others. When results are retrieved, entity "matches" is updated with that value.

4.4 Functionalities

4.4.1 Overview

This application has different functionalities. The most important ones are already integrated, and the ones which are not are described in the future work chapter at the end. When investigator opens the application and the config file is not defined yet, *installation procedure begins*. This procedure prepares the environment so that it can be used with this application. After installation all other functionalities appear. All of them are described and shown in the sub-chapters below.

4.4.2 Installation

The first thing that installation wizard shows are instructions to grant access to the web server so that it gets access to all folders and subfolders where this application is installed. Next Moss script is downloaded and configured. User must first receive user ID for Moss. If this number is not given, script does not work. Instructions on how to get that code are provided in the help menu in the application. This step is shown in Figure 4.3. Next step is to configure connection with MySQL database. Server address, username, password and database name must be provided. If connection fails, user must re-enter data. If connection succeeds, installation wizards checks whether database with that name already exist. If it does exist it uses the given database and if not, a new one is created with corresponding entities, attributes and keys. This step is shown in Figure 4.4. Third step is where user enters Social Media keys and tokens. If tokens are not available, functionalities to check person relationships will be disabled. This step is shown in Figure 4.5.

Given that data, config file is created. Example of config file is shown in Code 4.1. Note that every data in config is retrieved from user input except Wkhtmltopdf data and number of first matches and social media start and end position. Number of first matches is predefined to ”10” and can be

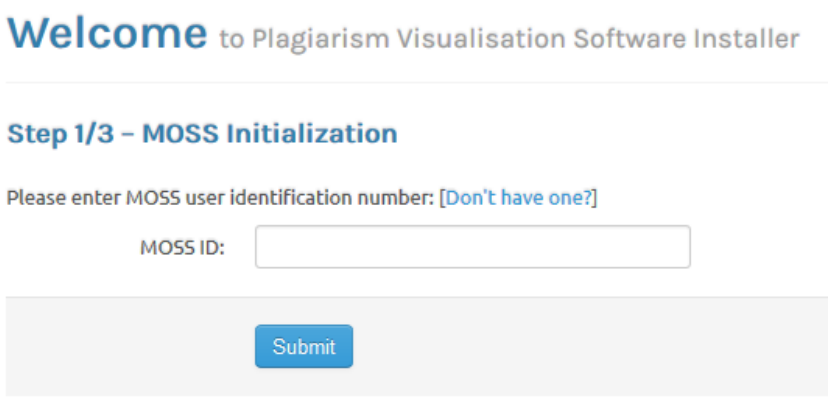


Figure 4.3: Screen capture of installation step 1

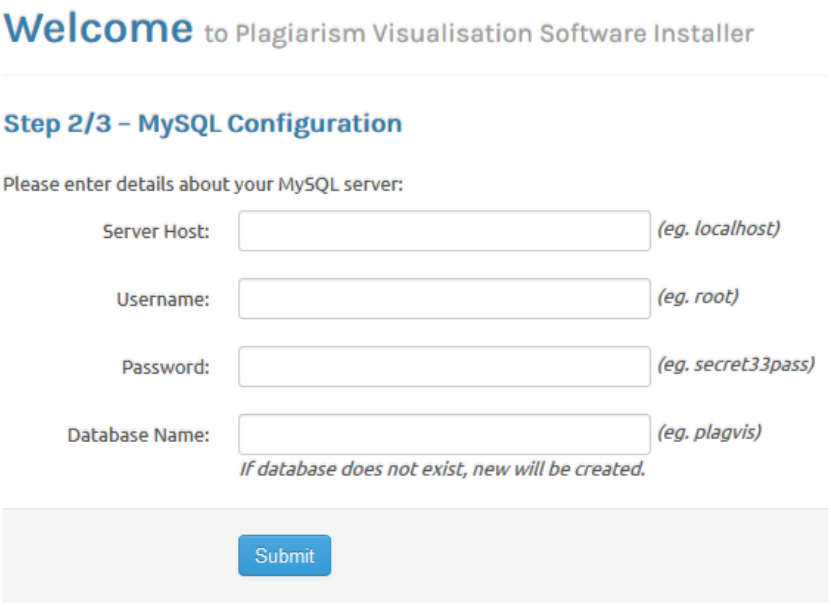


Figure 4.4: Screen capture of installation step 2

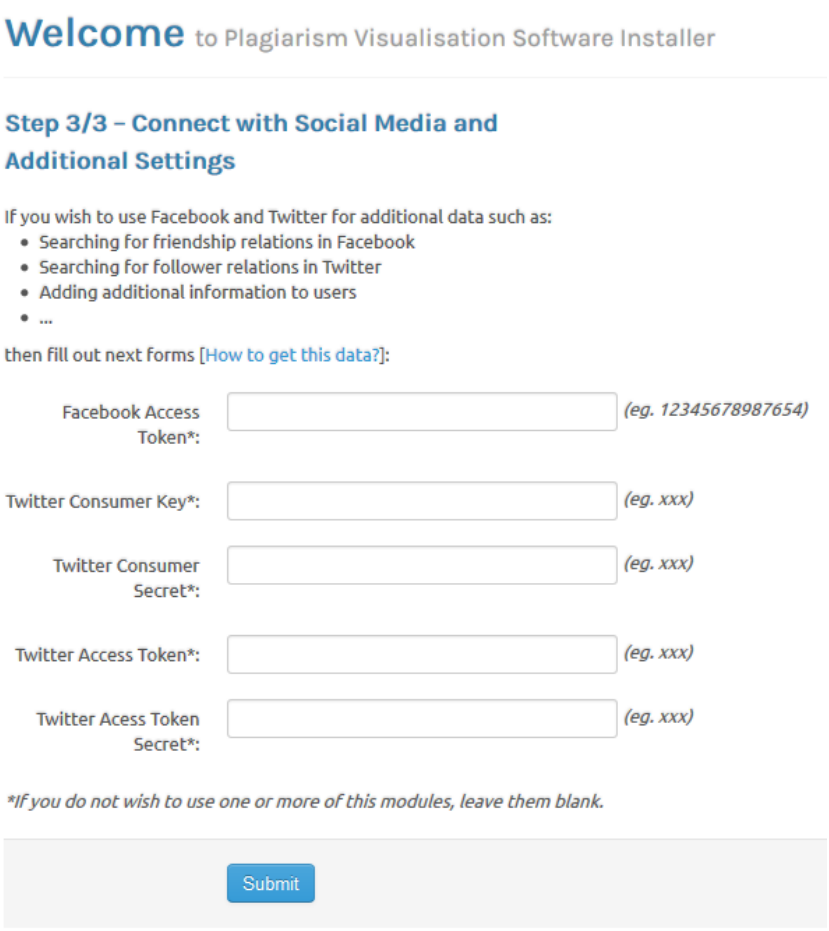


Figure 4.5: Screen capture of installation step 3

later changed in the settings section. The same goes with social media start position which is set to "0" and end position to "10". To put visualisation images in PDF report, Wkhtmltopdf is required. Installation procedure for Wkhtmltopdf is described in Chapter 3.6. If this application does not exist it will be disabled. If it does exist it will be enabled.

```
<?php
////////////////////////////////////////////////////////////////////////
// //
// Plagiarism Visualisation Config File
// User settings
// //
////////////////////////////////////////////////////////////////////////

// Database configuration (MySQL)
$db_host="localhost";
$db_user="username";
$db_pass="secretpassword";
$db_name="plagvis";

// Facebook configuration
$fb_access_token="exampleFacebookAccessToken123";

// Twitter configuraiton
$tw_consumer_key = "exampleTwitterConsumerKey";
$tw_consumer_secret = "exampleTwitterConsumerSecret";
$tw_access_token = "exampleTwitterAccessToken";
$tw_access_token_secret = "exampleTwitterAccessTokenSecret";

// Google search keywords
$google_search_keywords=array("stanford");

// Show number of first matches at visualisation
$number_of_persons_similarity=10;

// Social media start and end position
$social_media_start_position=0;
$social_media_end_position=10;

// If wkhtmltopdf is enabled
$wkhtmltopdf = 1;
?>
```

Code 4.1: Example of Application Config File

4.4.3 Project

When user goes on to the projects overview site all available projects are presented. This is shown in Figure 4.6. Note that projects with attribute project_status set to "2" are not shown. In this page all projects are shown and the number of assignments that each project has is also shown. Beside that there are two buttons, one is "View" and the other is "Delete". Clicking on button delete will disable this project, all corresponding assignments and all matches that correspond to each assignment in project. If user clicks on the name of the project or button "View", the window described later is shown. If there are no projects available to show (i.e. *database is empty or all projects were deleted*) the button to create new projects is shown. If user clicks on that button it redirects him to the "Add New Project" page which is shown in Figure 4.7. In that page the user can create new project. Name of the project and number of assignments must be presented. If number of assignments is not entered, by default one assignment will be created. If user creates project with zero assignments, one assignment will still be created. If this number is lower than zero it will be converted to a positive number and that number of assignments will be created. If number of assignments is greater than 50, only 50 assignments will be created. This limit is added, for the case that the user accidentally enters a too big number. If this number is not a number, error occurs and user needs to re-enter data. Note that user can add new assignments later as well. Assignments will get default names "1", "2", "3" and so on. When new project and assignments are created, they are put in database and local folders are also created.

When user clicks on the desired project, site as shown in Figure 4.8 is shown. In this example project has one assignment. This assignment already has some submissions uploaded but they have not yet been checked with Moss. This can be seen in Status section which in this case shows "Moss NOT checked" in orange colour. Option to check with Moss is also presented. Whenever at least one assignment exists that has not yet been checked with Moss, this option will be shown. If all assignments have been checked this

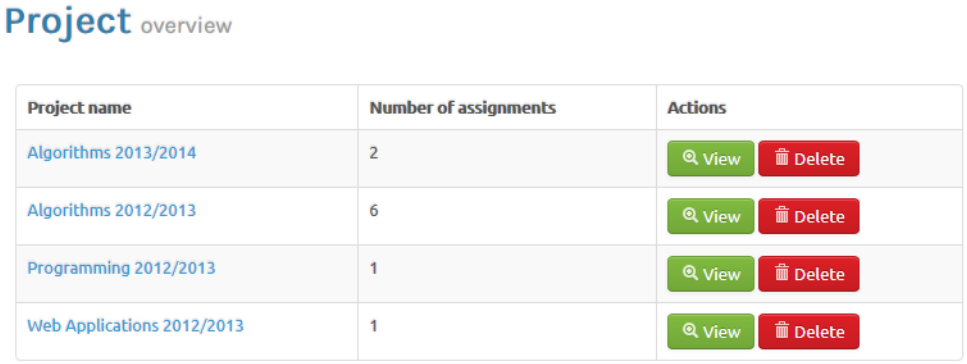


Figure 4.6: Screen capture of Project Overview section

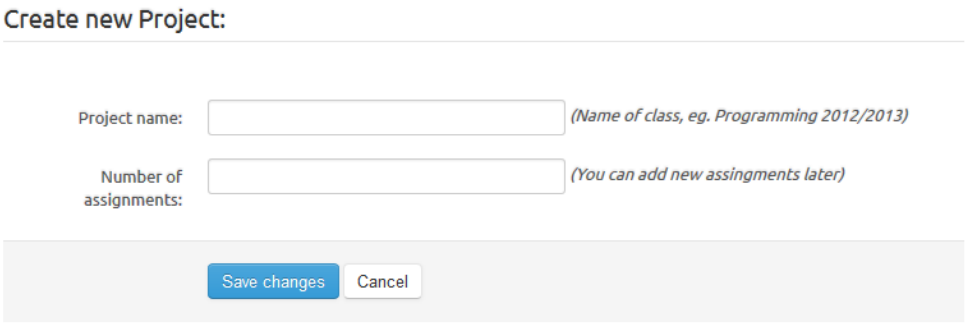


Figure 4.7: Screen capture of Add new Project section

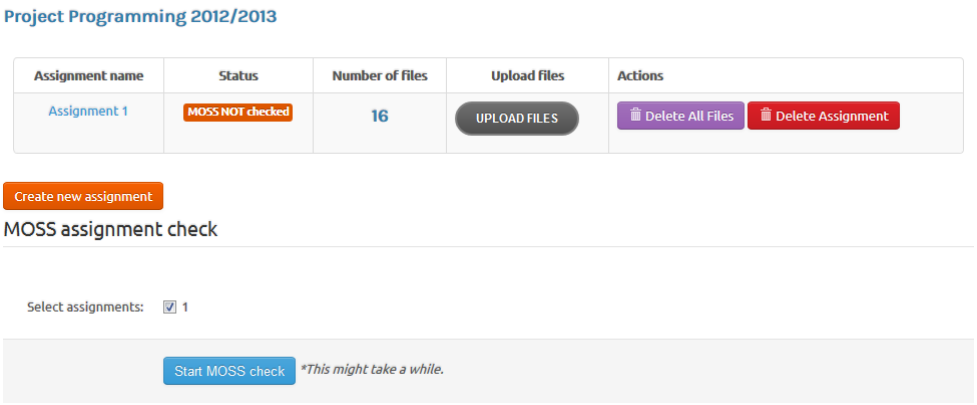


Figure 4.8: Screen capture of specific project overview

will not be shown and Status section will show "Moss checked" in green colour. Also there is always button to create new assignment shown and available. User can always upload new files even though assignment has already been checked with Moss. In that case Moss check must be repeated. Until this is done old matches will be available. After new Moss check is done old will be disabled and new will be shown. This means that every data about matches (*not checked, confirmed, rejected*, which will be described in Chapter 4.4.5) is deleted. User has also option to delete all uploaded files. Note that deleting files will result in irreversible action which cannot be undone. Deleting assignment however can be partially reversible. Data which is stored locally is not deleted and data which is stored in the database in only disabled. Functionality that can reverse deleting assignments has, however, not yet been implemented. If user wishes to do this, he can manually override the data in database. Note that data about matches status will be irreversibly deleted. This is due to the fact that attribute "match_status" has four options (*not checked, confirmed, rejected and disabled*) and overwriting status to disabled will erase old state. User also has option to view desired assignment and this is described in Chapter 4.4.4. For this to happen, user can click button "View" or click on the assignment name.

After Moss check has been done (described in Chapter 4.2), new func-

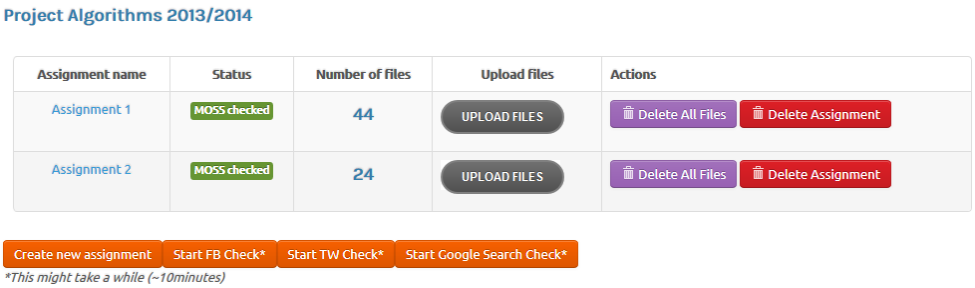


Figure 4.9: Screen capture of specific project overview

tionalities are enabled and shown. New functionalities are "Start FB Check", "Start TW Check" and "Start Google Search Check". This three functionalities are explained in Chapter 4.3. Example is shown in Figure 4.9. Note that buttons to check for Facebook and Twitter matches are shown only if tokens are provided in config file. If they are not provided, this functionality is disabled in will not be shown. Google Check is always available because no login is required.

4.4.4 Assignment

When user clicks on the desired assignment, data concerned with this assignment is shown. At the top of the site there is some basic statistical data which is shown in Figure 4.10. This functionality covers the following data:

- Number of matches that were detected in current assignment
- Average similar lines that were among all detected matches
- Maximal similar lines that were among all detected matches
- Average similarity that was detected through every match (first average between two users in one match is calculated and then average of all those averages)
- Maximal similarity that has been detected (from average of both similarities in one match)
- Minimal similarity that has been detected (from average of both similarities in one match)
- Number of matches that have not yet been checked (i.e. *confirmed or rejected*).

In that part there is also functionality to reject all non-checked matches. When user confirms or rejects some matches, he can decide to stop checking. Usually user does not check every match but only first few, or those that have large similarity. With that button he rejects all other matches and thus examination in this assignment is completed.

The other section in this assignment view is a list of all matches. Example is shown in Figure 4.11. Every match has two persons. In first column there is the first person and in second column there is the second person. The third column shows average similarity between these two persons. Fourth column shows how many lines were found similar between these two persons' submissions. The fifth column shows whether a specific match was

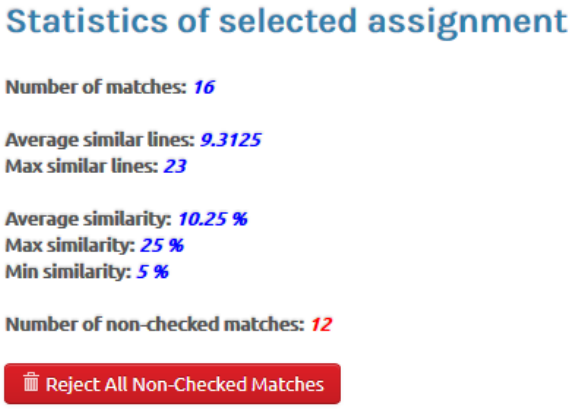


Figure 4.10: Screen capture of specific assignment statistical data

confirmed, rejected or nothing was done yet. In the last column there are different buttons. Button "View Match" shows details between the first and the second person and this is described in Chapter 4.4.5. The second button "View Result" redirects the user to Moss results and this is described in Chapter 4.4.6. After the user has checked for similarity he can choose between buttons "Confirm Match" and "Reject Match". With that status in the selected match changes. The last section in this assignment view is a list of all persons which appear in detected matches. Example is shown in Figure 4.12. It contains three columns. First is the name of person. Second is ID of the person. Third has option to view specific person and is described in Chapter 4.4.7. Note that all names as well as all ID numbers in this examples are fictional. Names are generated from a list with most common American names and surnames.

Person 1	Person 2	Similarity	Number of same lines	Status	Actions
James Smith	John Anderson	25 %	15	CONFIRMED	View Match View Result Confirm Match Reject Match
William Young	David Walker	18 %	19	REJECTED	View Match View Result Confirm Match Reject Match
Robert Lewis	Michael Lee	17.5 %	17	CONFIRMED	View Match View Result Confirm Match Reject Match
Richard Wright	Charles Green	14 %	23	REJECTED	View Match View Result Confirm Match Reject Match
Charles Green	Thomas Parker	8.5 %	6	REJECTED	View Match View Result Confirm Match Reject Match
Charles Green	Eric Moore	8.5 %	5	REJECTED	View Match View Result Confirm Match Reject Match
Charles Green	George Miller	8.5 %	9	REJECTED	View Match View Result Confirm Match Reject Match
George Miller	Kevin Russel	8.5 %	9	REJECTED	View Match View Result Confirm Match Reject Match
Thomas Parker	Eric Moore	7.5 %	5	CONFIRMED	View Match View Result Confirm Match Reject Match
Richard Wright	George Miller	7.5 %	9	NOT CHECKED	View Match View Result Confirm Match Reject Match
James Smith	Scott Taylor	7.5 %	1	NOT CHECKED	View Match View Result Confirm Match Reject Match
James Perkins	Scott Taylor	7 %	1	REJECTED	View Match View Result Confirm Match Reject Match
Charles Green	Kevin Russel	7 %	9	NOT CHECKED	View Match View Result Confirm Match Reject Match
William Young	Peter White	6.5 %	11	NOT CHECKED	View Match View Result Confirm Match Reject Match
James Smith	James Perkins	6.5 %	1	CONFIRMED	View Match View Result Confirm Match Reject Match
Richard Wright	Kevin Russel	6 %	9	NOT CHECKED	View Match View Result Confirm Match Reject Match

Figure 4.11: Screen capture of specific assignment list of matches

Person	ID	Actions
Charles Green	10090090	View
David Walker	10090052	View
Eric Moore	10080165	View
George Miller	10090057	View
James Smith	10090101	View
James Perkins	10090114	View
John Anderson	10090105	View
Kevin Russel	10090035	View
Michael Lee	10080040	View
Peter White	10090055	View
Richard Wright	10090058	View
Robert Lewis	10090038	View
Scott Taylor	10080080	View
Thomas Parker	10080167	View
William Young	10090112	View

Figure 4.12: Screen capture of specific assignment list of persons

4.4.5 Match

When user wishes to see a desired match, three sections are shown. Example is shown in Figure 4.13. The first person of selected match is shown on the left side. His name and user ID are shown. If user clicks on name he is redirected to user page which is described in Chapter 4.4.7. If Facebook or Twitter search was started, data about number of results is shown. In this example the first person corresponded to one Facebook and one Twitter account. For the second person two Twitter accounts were found and eleven Facebook accounts. If user confirmed the account, it is shown that account is confirmed. In this particular example, images from Facebook or Twitter should be shown in Person section, where silhouette of person is shown in this example. This image was intentionally removed. If there is no Facebook or Twitter account found this image is shown as well. If an account is found, profile image of confirmed account is shown. First it checks if Facebook account is confirmed. If it is, this profile image is shown. If not, it checks whether Twitter account is confirmed. If it is, then this profile image is shown. If no account is confirmed, the first Facebook account is shown. If there was no Facebook account found, the first Twitter account profile is used. If Facebook and Twitter search was not started, there is no data about number of accounts matched (*Facebook and Twitter are treated separately*).

The third section shows information between these two persons. If Facebook search has been started, information about Facebook connections is shown. If there was no friendship match, this is shown in green colour. If there was a Facebook connection found then this is shown in red colour and warning sign. If there was no Facebook search started, button to start search is shown. This functionality first checks if there is at least one Facebook account in each person available. If there is not, algorithm first searches for accounts. After accounts were found, or had already been found before, algorithm checks automatically for matches. If there is any confirmed account, only this account is used. Deleted Facebook accounts are not used for relation search. If a person's Facebook account is added manually, option to

recheck relations is shown. If this is done, previous data about relations is deleted and is searched again. The process is the same with Twitter. The only difference is that the direction of friendship is shown as well. The process is then the same as with Google with the difference in information output. If there was any result found statistical data from database is shown. The following data is presented: average number of results for those matches that were confirmed, those matches that were rejected and those matches that have not yet been checked. This data includes all data in database and not just data from the current assignment or project. Information of how many results were found on Google can't help user if he does not know what are the averages. If for example average result for rejected matches was near zero and average result for confirmed matches was around number ten, that would mean that possibility of these two persons knowing each other is greater than if they did not know each other. If Google Search was not yet started, button to start Google search for this match is shown. At the bottom of this site information about these two persons matches is shown. For every assignment, where similarity was found in the current project a new row is generated. The first column shows the name of the assignment. The second column shows the number of lines that were found similar in that assignment submissions. The third shows average similarity in that match. The fourth column shows status, whether this match has already been rejected or confirmed. The fifth row has three options. The first one is to view Moss results, the second one is to confirm the selected match and the last one is to reject it.

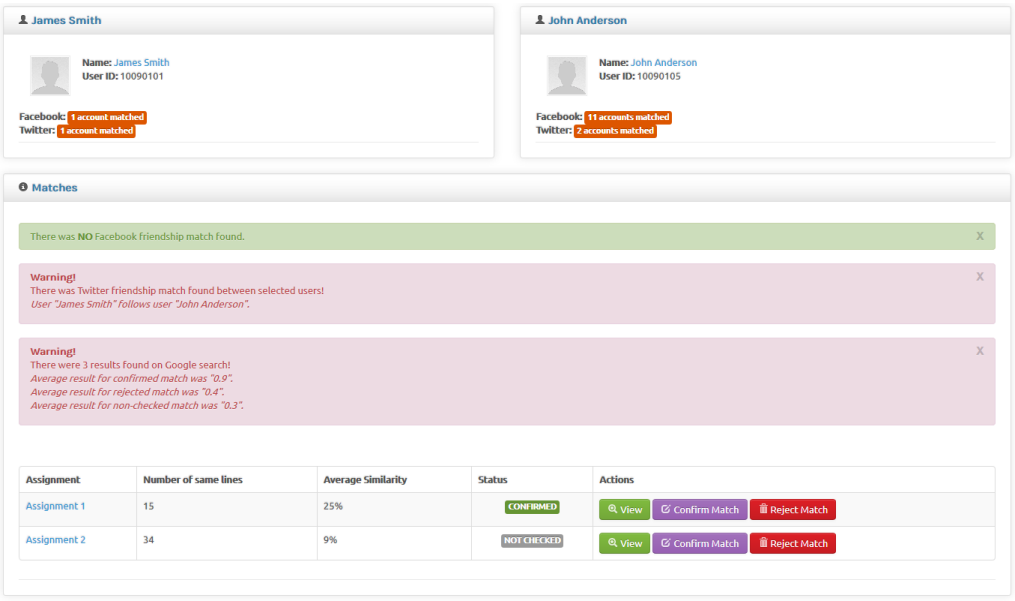


Figure 4.13: Screen capture of viewing a specific match

4.4.6 Result

When user wishes to see a desired Moss match, he is redirected to appropriate URL. Note that because Moss software deletes results after some time, they were downloaded locally. Example of how this results can be seen is shown in Figure 2.2. This page opens in a new window, so user can easily go back to match and confirm or reject it.

4.4.7 Person

When user clicks on person, information about that person is shown. Example is shown in Figure 4.14. This part is also divided in three sections. The first section includes person's name and ID. Profile image is selected like it is selected when viewing a match. The second section shows information about Social media. If Facebook or Twitter accounts exist they are shown here. Links to their sites are provided so user can check them. If there are no matches, it shows that there are no matches found. If Facebook or Twitter search has not yet been started, options to automatically check for Facebook account or Twitter accounts is shown (*if available*). There is also option to manually add Facebook or Twitter account. If user manually adds a new account, this account is then considered as confirmed, and others become hidden. If then the user wishes to add a new account, this one has to be un-confirmed first. User can also manually confirm accounts that were automatically found. Last option here is to delete account and consider it as incorrect. Note that if a new account is added manually, button to recheck for friendship relations appears when viewing matches. When rechecking for relations only confirmed account is used. Third section shows every match where this person appears. This information is divided by assignments and this specific person can have multiple matches with different persons in that assignment. Other information that is shown is trivial, as it was previously described.

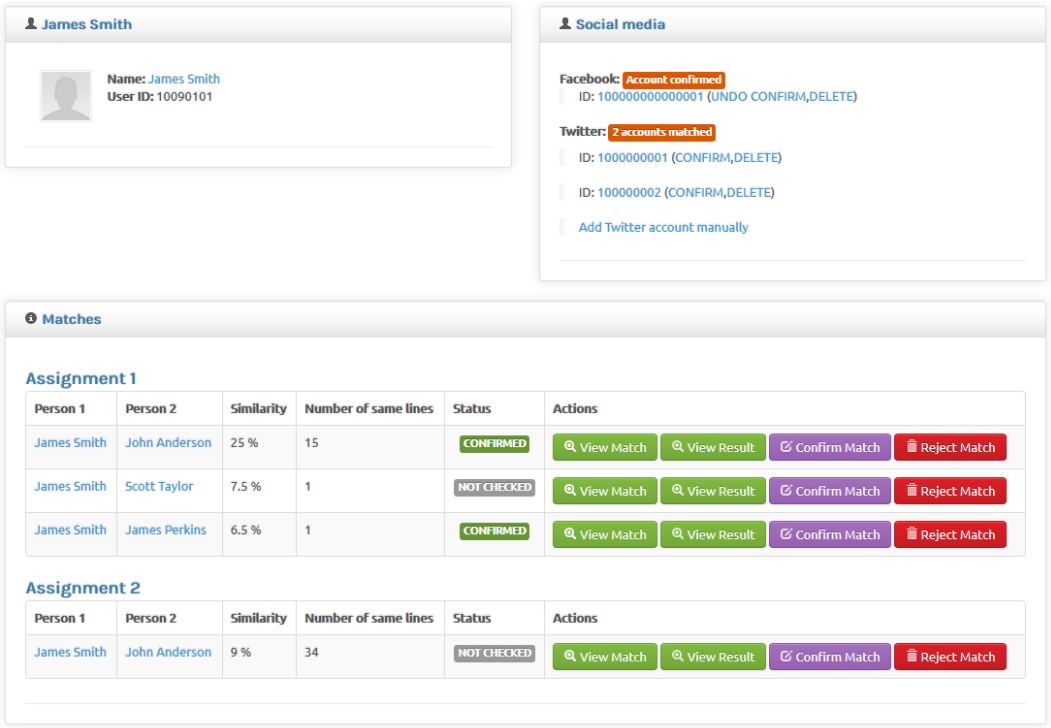


Figure 4.14: Screen capture of viewing specific person

4.4.8 Visualisation

When user wishes to see visualisations or create report, "See Visualisation" site must be opened. Example of how this page looks like is shown in Figure 4.15. As can be seen from this example, every project is presented. User can view project name, number of assignments in that project and option to view different visualisations and PDF report. If user clicks on button "Graph" he will be redirected to Force-Directed Graph visualisation which is described in Chapter 4.5.1. If user clicks on button "Co-Occurrence Matrix" he will be redirected to Co-Occurrence Matrix visualisation which is described in Chapter 4.5.2. If user clicks on button "PDF Report" a new window will open where PDF report is generated. This is described in Chapter 4.6.

If user clicks on project, almost the same site is shown. The difference is that instead of project list there is assignments list. User can also see visualisations or create PDF report for each assignment only. In that case only matches from the selected assignment are used. The other difference is that instead of column that shows the number of assignments next to the project name is here a column that shows the number of matches in each assignment. If user clicks on assignment name he is redirected to the page where information about assignment is shown.

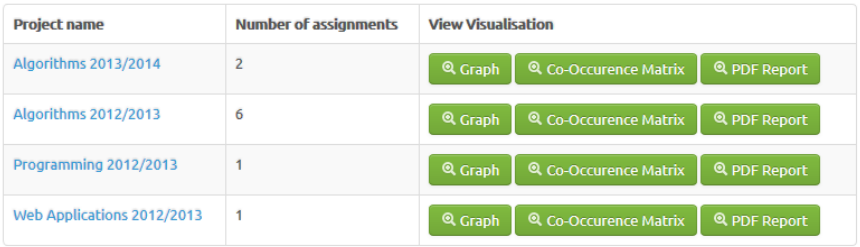


Figure 4.15: Screen capture of visualisation projects listing

4.4.9 Settings

Example of how settings page looks like is shown in Figure 4.16. On this site, user can change four parameters:

- User can enter Google search keywords (described in Chapter 4.3.3)
- User can enter how many first matches are shown in visualisations by default
- User can enter social media start position (described in Chapter 4.3.1)
- User can enter social media end position (described in Chapter 4.3.1)

The first and the last two options are described in previous chapters. The second one is required because Moss check returns by default maximum of 250 results. This means 250 matches are created in database. When opening visualisations, this number of matches is too big to be shown appropriately. That is why only the preset number of matches is shown when user opens visualisation. Note that number of matches can be changed in visualisation site, but default is preset in settings. This number can also be zero which means that all matches are going to be shown in visualisation. Note that if 250 matches are going to be shown in visualisation this can be too complex for computer to draw and it can be impossible to see anything in visualisation.

4.4.10 Report Settings

Report settings have so far only option to *enable or disable* showing generated visualisations in PDF report. Note that if application called "Wkhtmltopdf" is not available, this option is disabled by default and cannot be changed. Visualisations in report thus cannot be shown. The reason why that is so is described in Chapter 3.6.

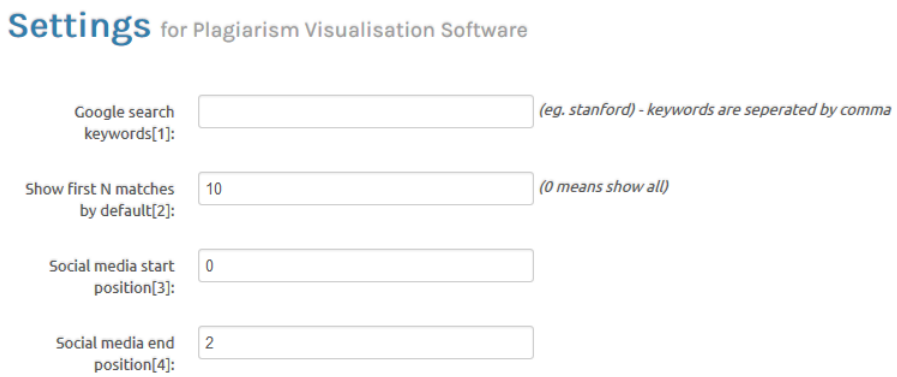


Figure 4.16: Screen capture of settings page

4.5 Visualisation

Generating visualisations is one of the most complex functionalities in this application. This is due to the fact that a lot of different data must be prepared for visualisation.

4.5.1 Force-Directed Graph

Theory

Example of how Force-Directed Graph visualisation site looks like is shown in Figure 4.17.

Each node represents a person that has detected similarity in one of the matches in the project. Above the node is text which shows ID of that specific person. When user goes over the ID, text font changes to bold. If user clicks on the person he gets redirected to that specific person's page, which is described in Chapter 4.4.7. Each node is connected to some other node with a link.

If there is a link between two nodes this means that these two persons have detected similarity in some of the assignments. Text above the node shows in which assignments this similarity occurs. At the beginning of the text, names of the assignments are shown and separated by comma. After

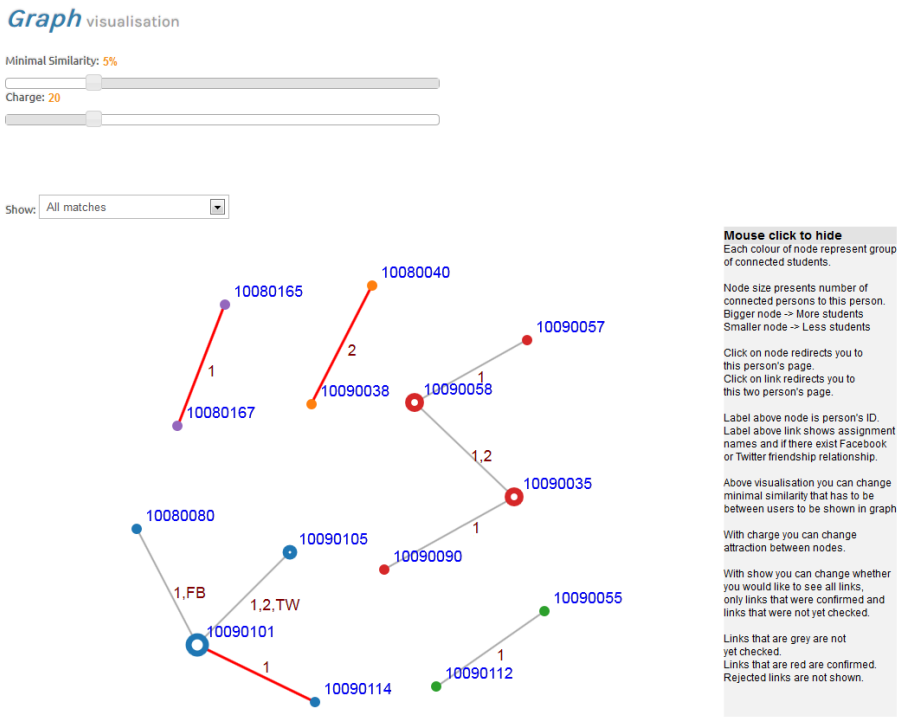


Figure 4.17: Example of Force-Directed Graph visualisation in application

that there is additional text "FB" or "TW". If there was Facebook or Twitter connection detected between these two users, this text is added so the user can see whether they are friends on a social media or not. Gray colour of link shows that the node has not yet been confirmed or rejected. Red colour of node, being slightly thicker, shows that this match is a confirmed match. Note that all matches in this connection must be confirmed to change colour. This happens when two persons have similarity in more than one assignment. Confirming only one would not result in link getting coloured. However if a match is rejected it will disappear from the visualisation. When user clicks on link, he is redirected to those two persons' match site, described in Chapter 4.4.5. This example shows that there are five different groups (*clusters*) of persons in this project.

Each group of persons (*cluster*) has its own colour so it can be easily distinguished from others. Colours of nodes do not represent anything else and are given randomly to the groups. Maximum number of different groups is 20 as this is the limit in application in different colours. More about colours is described in a later section. There is yet another thing in the graph and that is the size of the node. Size of the node (or *degree of node*) represents to how many other nodes this node is connected. If node is connected to another node twice or more (e.g. two assignments or more), this also counts as to how many nodes is connected. Facebook and Twitter connections however do not count. In this example the person with ID "10090090" is connected to the person with ID "10090035" only with one assignment. Hence the size of node "10090090" is $x * 1$, where x has specified size defined by the following rule. If there are N maximum connections between two nodes in the whole graph, then the smallest node has size $(1/N) * 10$ pixels. That number represents x. So the size of that node is 1 pixel. Node "10090035" however is connected to node "10090058" with two connections, resulting this node having size $x * 3$ (one connection to node "10090090" and two connections to node "10090058"). Sizes of nodes are therefore dynamically defined by maximum number of connections between two nodes. In reality the node is

not x pixels, because circle that presents node has some thickness as well.

At the top of Figure 4.17 other settings for visualisation are presented. Dropdown menu called "Show" specifies which matches are shown in visualisation. By default all matches are shown, except those which are rejected. Other options are to show only non-checked matches and only checked matches. Next thing the user can change is so called "Charge". Charge defines attraction between nodes, where "0" means almost no attraction (*actually means repulsion between nodes*) and "100" means more attraction. The last option is called "Minimal similarity". This defines what is the minimal similarity that has to be in a match to be shown in visualisation. Default value is set according to the settings which were described in Chapter 4.4.9.

There is also help menu on the right side of visualisation and shows basic information about visualisation.

Implementation

Implementation of Force-Directed Graph visualisation is divided in two sections. First is preparing data for visualisation and second is generating visualisation.

At the beginning required parameters are stored. These are project or assignment ID, minimal similarity and show data. If minimal similarity is not set, it is retrieved from the database based on defined settings. Then set of links is generated (*called linkSet*). Matches are retrieved from database according to minimal similarity, show settings and the project or assignment ID. Source ID and target ID are stored to linkSet. Then similarity of that match is stored in value attribute in linkSet. Link name is stored as well, defined as described previously. Status of the match is also stored, so visualization algorithm knows whether it has been confirmed or not. Link to website is stored in linkSet which points to where match information is. Example of linkSet is shown in Code 4.2.

```
var linkSet = [
        {sourceId: "10", "value":25,  linkName: "1,2,TW", targetId: "11",
            status: "0", elink: "?view_match=10&match2=11"},
        {sourceId: "12", "value":17.5,  linkName: "1", targetId: "13",
            status: "1", elink: "?view_match=12&match2=13"},
];

var nodeSet = [
        {id: "10", name: "10090101", group: "0", hlink: "visualisation.php?
            view_p=10", count: "2"},
        {id: "11", name: "10090105", group: "0", hlink: "visualisation.php?
            view_p=11", count: "2"},
        {id: "12", name: "10090038", group: "1", hlink: "visualisation.php?
            view_p=12", count: "1"},
        {id: "13", name: "10080040", group: "1", hlink: "visualisation.php?
            view_p=13", count: "1"},
];
```

Code 4.2: Example of linkSet and nodeSet required for Graph visualisation

After that, set of nodes is created (called *nodeSet*). To get cluster information, algorithm by Csaba Gabor is used and modified [23]. Algorithm originally returned warnings, because when calling function *array_merge* this function sometimes did not receive array but only one value (which was always *null*). This was modified by checking whether a given parameter is array or not and if it is not, then this part was ignored. This algorithm goes through all match data and outputs nodes that are connected to each other, separated by clusters. Each person is then given cluster ID (*group*). All data, including person ID, name, cluster ID, link to person's web page and number of how many are connected to this node is stored to nodeSet. Example of nodeSet is shown in Code 4.2.

Now that data is prepared, visualisation can be created. At the beginning default D3 settings are set. Template, mentioned in Chapter 3.4.2 is used for Force-Directed Graph. Depending on the number of different clusters, one of the following color scales already implemented in D3 is used.

```
colorScale = d3.scale.category10();
colorScale = d3.scale.category20();
```

If there are ten or less clusters, the first command is used. If there are more, the second is used. Normally more than twenty clusters are never used, as visualisation would become too complex. This is separated because if only ten colours are used they can be more easily distinguished than those defined by twenty colours.

After that other settings such as colour of link, thickness of link, size of node are defined. After that text with link is added to nodes and links. With all that being specified visualisation is created. Other functions such as setting the minimal similarity, charge and which matches are shown can be looked up in the source code.

4.5.2 Co-Occurrence Matrix

Theory

Example of how Co-Occurrence Matrix visualisation site looks like is shown in Figure 4.18. Each cell represents a specific match. Colour of each cell is defined by the cluster it belongs to. Cell opacity presents average similarity between these two persons. The darker the cell, more similarity is between two persons. The brighter the cell, less similar are the matches. On the left and upper side of the matrix are IDs of corresponding matches. Similarity between two persons is always 100%, hence the dark cell. If user does not wish these cells to be coloured, he can disable that by checking box "Hide similarities between same users". Cell opacity is also normalized, because opacity would be too low in normal cases. Similarity of 20% would result in cell opacity being only 20%, that is why opacity is normalized by the highest similarity. This means that if the match with the highest similarity has similarity 20%, it would have opacity 100%. Every other match then has opacity normalized by this 20%, except those in diagonal which always have 100% opacity.

When user goes over the cell with mouse, average similarity is shown. This average similarity is average in a match and overall average over all

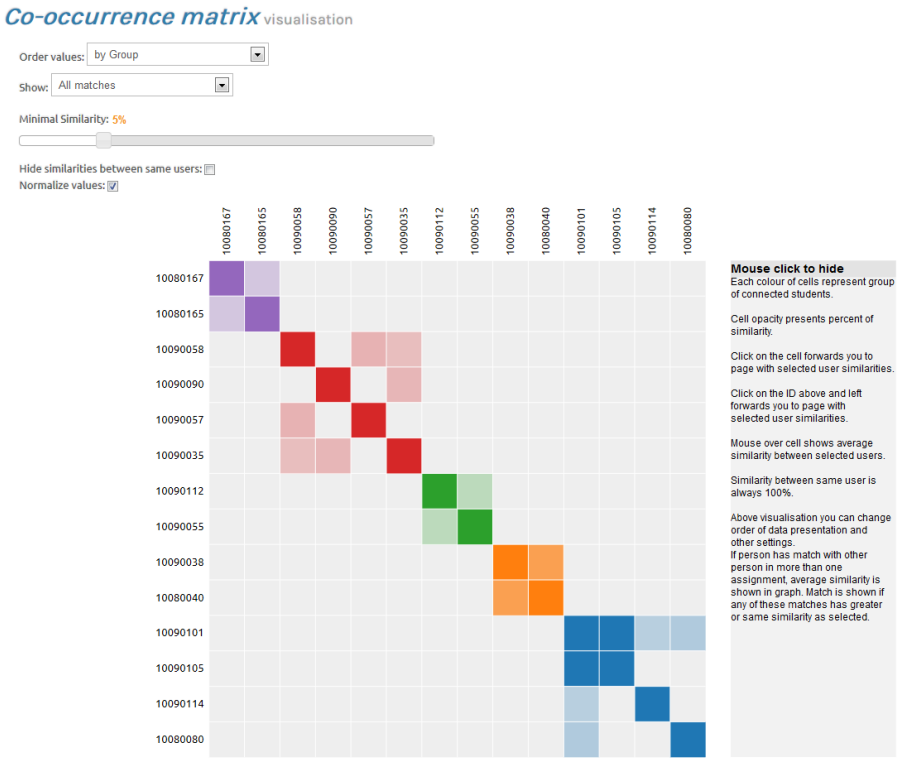


Figure 4.18: Example of Co-Occurrence Matrix visualisation in application

assignments. If the user clicks on the cell he is redirected to the match website which is described in Chapter 4.4.5. Clicking on IDs at the top and left side redirects the user to the person's website which is described in Chapter 4.4.7.

User has some other options available as well. Along hiding similarities between same users he can also denormalize or normalize values again. Minimal similarity is the same as it is in Graph visualisation. Default value is set according to the settings, which were described in Chapter 4.4.9 and can be changed manually. User can also select which matches are shown in visualisation. By default all matches, except those which were rejected are shown. Other options are to show only non-checked matches or only confirmed matches. The last option which is implemented is how cells are ordered in matrix. By default they are ordered by group (*by cluster*). Other options are that they are ordered by name (*ascending in alphabetical order*), or that they are ordered by similarity (*descending by similarity value*).

There is also help menu on the right side of visualisation and shows basic information about visualisation.

Implementation

Implementation of Co-Occurrence Matrix visualisation is also divided in two sections. First is preparing data for visualisation and second is generating visualisation.

Preparation of data is very similar to that in Force-Directed Graph visualisation. The only difference is that nodes need to be arranged in ascending order by ID and must start with zero. This is how implementation of Co-Occurrence Matrix mentioned in Chapter 3.4.2 requires it. Data in nodeSet and linkSet are the same as they are in Graph visualisation, except that here the status of match and number of connected nodes is not required and thus not generated. Example of linkSet and nodeSet is shown in Code 4.2 (*except that there is no data about match status and number of connected nodes, and IDs start with zero ascending by ID*).

Functions such as setting the minimal similarity, which matches are shown, and others can be looked up in the source code but the idea is the same as it is with Graph visualisation.

4.6 Generating Report

The user has two options when generating report. One is to create a report based on project data and the second is based on assignment data. Report based on project data includes all assignments that are in a specific project, whereas reports based on assignment data include only data from that specific assignment.

By default only confirmed matches are shown in the report. The purpose of generating report is to print only confirmed data not printing all available data. Report covers following data:

- All persons' IDs and corresponding names that are included in confirmed matches separated by groups in which they are connected
- Similarities for each match, separated by assignments
- Co-Occurrence Matrix Visualisation
- Graph Visualisation

Note that visualisations are shown in the report only if they are enabled in the Report Settings page. Report that is generated opens in a new page and can be saved as PDF or printed. Visualisations are retrieved using application called "Wkhtmltopdf". This application receives URL address of desired website as input attribute and exports PDF generated from that site. A special attribute called "gen_pdf" is added to the visualisation section. If this attribute is added to visualisation site, only visualisation is shown. That means no settings menu is available, no help, no other options (and no website template either). With starting Wkhtmltopdf and passing the appropriate

URL as parameter, PDF is generated which includes that visualisation. This PDF is then imported into final report.

Chapter 5

Conclusions and Future Work

5.1 Results

As it was shown in previous chapters, this application provides an investigator with many assisting methods to discover plagiarism. These methods can provide valuable information as well as simplify plagiarism detection process. Creating this prototype application revealed many problems, which were encountered during development. Some were solved and some were not and are described in Chapter 5.2. There are also many functionalities that have not yet been implemented and are mentioned in Chapter 5.3. These functionalities can help investigator even more, but are not needed for basic use.

The application which was developed in this diploma thesis is also available on-line on the site called Github [24]. Source code is licensed under Creative Commons Attribution Share Alike 2.5 Slovenia license. This is the same license under which this diploma thesis is licensed. Note that application also uses the web template which is licensed under Apache License, Version 2.0 [19]. Differences that were made in web-template are declared in files that were changed. Other files only use this template and thus differences are not declared. However, the license is written in every file and it states that source code is my work, while the web template is the work of its

creator. Github project is available on site `https://github.com/mziga/pda` and can be downloaded to desired location where application is going to be used. Instructions on how to use the application and how to install it are provided in this diploma thesis and in *readme.txt* file included in repository.

5.2 Problems

During the development of this application, many problems occurred. First problem is that Facebook and Twitter require access tokens to grant access to their data. Even though required data is public, they still provide that data only through their APIs. To have access to this API, user needs to be registered and create an application to retrieve required tokens. This problem remains unsolved and cannot be bypassed. User has to have an account.

The second problem that occurred is that Facebook, Twitter and Google API all have limitations on how many queries can be made in specific amount of time. This problem was resolved by limiting which persons and matches are checked on these social media sites. User can start automatic check for first N matches, where N presents number of matches that are going to be checked. User can also manually check for each account on user page or manually check for relations on each match. This is how these limitations are bypassed if user wished to check every account and every match. There is also one other solution to this problem but would most probably work only for limited period of time, if it would work at all. The solution would be to parse data from websites and those limits would not apply here. This kind of solution was checked with Google but it resulted unsuccessfully. Google detected that algorithm might not be a real person and asked for Captcha code, which made this functionality inoperative. What would happen on Facebook and Twitter was not tested. It was not tested because even if it worked, it could work only temporary and thus was not implemented. Facebook and Twitter change their sites from time to time and this would result in an inoperative algorithm.

Next problem which is worth mentioning has occurred when generating the report. The idea of creating report is to have all investigated data in one piece, which can be saved locally or printed. Report includes data about different groups of connected people, their similarities and visualisations. The problem occurred because visualisations are generated with library that works on JavaScript. JavaScript is not generated on the server side, but on client side. This means that visualisations cannot be saved as they are generated only in client browser. Solution to this problem is that some kind of browser must be started on server side and snapshot from that browser is stored. This was done with application called "Wkhtmltopdf", which acts as a browser and stores what is shown. Details about that can be read in Chapter 3.6. This application then received input URL, where visualisation is created and then stored it in PDF format. When generating the report with application called "FPDF", these two files were included in the final report.

One problem was also that Moss stored results of matches only for limited period of time. That means if original link to results was stored then some time later this would not be accessible anymore. Solution to this problem was to download all reports generated by Moss and store them locally. Links in these files were needed to be changed as well, so that everything worked locally.

There were some other minor problems as well but are more of implementation nature and do not need to be particularly explained.

5.3 Future Work

In the course of developing this application many ideas of how to upgrade the application and extend its functionalities came up. Some were already implemented and some not yet.

As it was mentioned in the introduction, this application can be used for free text plagiarism detection as well. Currently it uses Moss to detect similarity, but other tools could be implemented. The idea is that when creating a project, user could select what kind of plagiarism is going to be checked. Selection would be whether this project is going to have source code or free text detection. Results would then also be stored along with the similarity data. Everything else would be the same then.

An extension to current application could also be to add extra-corpal plagiarism detection. This means that application would check source code (*or free text if implemented*) on search engines as well. If match would be found then this would be added in database as well. URL of detected page would be stored as node, and then person would be connected with that node in match. This would then be shown in visualisation as well and investigator could clearly see if two or more persons copied from the same source on the internet.

When generating visualisations, many other parameters could be changed as well. One option would be to manually add persons directly on Graph visualisation and connecting it to other nodes. In graph visualisation user could get some tool tip, which would show more information on this match or person. This is already implemented in Co-Occurrence Matrix visualisation.

There could be many more parameters in report settings as well. Now only four options of report are available. One is generating report based on project and second one is based on assignment. Both can have visualisations in it or not. An extension would be to add source code (or *free text if implemented*), so investigator would have evidence of plagiarism in that report.

Another option would be to add retrieved social media information or information from Google (*friendship relations are currently shown only on Graph visualisation*). Perhaps different options for visualisations would be available as well. Currently only confirmed matches are shown in report.

Functionalities in this application could also be implemented in applications which are already used in universities or schools (e.g. *Moodle*). This would then be some kind of plug-in or extension and investigator would not need to save submissions and then re-upload it to this application but do everything there.

There could also be an upgrade on this application with the use of jQuery [25], which was not implemented as this application is only prototype.

As it is evident, this application can be very widely extended and not much is done in this area yet. If there is a need to extend this application with previously mentioned functionalities, then results of this diploma thesis could be used in next versions. Note that this application is only a prototype and there is probability that some bugs can occur. Even though application was tested repeatedly, perfect performance cannot be guaranteed.

Bibliography

[1] M. Witherspoon, N. Maldonado, and C. H. Lacey, "Undergraduates and Academic Dishonesty," *International Journal of Business and Social Science*, vol. 3, no. 1, pp. 1-6, January 2012.

[2] T. Lancaster, "Effective and Efficient Plagiarism Detection," PhD thesis, South Bank University, London, 2003.

[3] F. Culwin and T. Lancaster, "Visualising Intra-Corpal Plagiarism," *Awaiting publication, available from South Bank University*, London 2001.

[4] J. Hage, P. Rademaker, and N. van Vugt, "A comparison of plagiarism detection tools," *Department of Information and Computing Sciences Utrecht University*, Utrecht, Tech. Rep. UU-CS-2010-015, 2010.

[5] "Sherlock - Plagiarism Detection Software." [Online]. Available: `http://www2.warwick.ac.uk/fac/sci/dcs/research/ias/software/sherlock`, [2013].

[6] "JPlag Detecting Software Plagiarism." [Online]. Available: `https://jplag.ipd.kit.edu`, [2013].

[7] "Moss, A System for Detecting Software Plagiarism." [Online]. Available: `http://theory.stanford.edu/~aiken/moss`, [2013].

[8] "Demonstration of JPlag." [Online]. Available:
`http://www.ics.heacademy.ac.uk/resources/assessment/plagiarism/demo_jplag.html`, [2013].

[9] "Demonstration of Sherlock." [Online]. Available:
`http://www.ics.heacademy.ac.uk/resources/assessment/plagiarism/demo_sherlock.html`, [2013].

[10] T.S. Harding, D.D. Carpenter, C.J. Finelli, and H.J. Passow, "The Influence of Academic Dishonesty on Ethical Decision-Making in the Workplace: A study of engineering students," *Proceedings of the 2004 ASEE Annual Conference and Exposition*, June 2004.

[11] "PHP." [Online]. Available:
`http://php.net`, [2013].

[12] "MySQL Database." [Online]. Available:
`http://www.mysql.com`, [2013].

[13] "Apache Web Server." [Online]. Available:
`http://www.apache.org`, [2013].

[14] M. Dewar. "Introduction," in *Getting started with D3*, California: O'Reilly Media, 2012, pp.1-6.

[15] "Force Layout." [Online]. Available:
`https://github.com/mbostock/d3/wiki/Force-Layout`, [2013].

[16] "Force-Directed Graph example." [Online]. Available:
`http://bl.ocks.org/mbostock/4062045`, [2013].

[17] "Co-Occurrence Matrix example." [Online]. Available:
`http://bost.ocks.org/mike/miserables`, [2013].

[18] M. Usman, "Charisma, Responsive Admin Template". [Online]. Available:
`http://usman.it/themes/charisma`, [2013].

[19] "Apache License, Version 2.0." [Online]. Available: http://www.apache.org/licenses/LICENSE-2.0, [2013].

[20] S. Schleimer, D.S. Wilkerson, and A. Aiken, "Winnowing: Local Algorithms for Document Fingerprinting." [Online]. Available: http://theory.stanford.edu/~aiken/publications/papers/sigmod03.pdf, [2013].

[21] "Twitter OAuth." [Online]. Available: https://github.com/abraham/twitteroauth/tree/master/twitteroauth, [2013].

[22] S. Konstantinidis, (2007, June), "Computing the edit distance of a regular language," *ScienceDirect*. [Online]. 205(9), pp. 1307-1316. Available: http://dx.doi.org/10.1016/j.bbr.2011.03.031, [2013].

[23] "Connected Components algorithm." [Online]. Available: http://bytes.com/topic/php/answers/743887-multidimensional-array-search-relationships, [2013].

[24] "Github." [Online]. Available: https://github.com, [2013].

[25] "jQuery." [Online]. Available: http://jquery.com, [2013].

List of Figures

List of Codes