Plagiarism detection for Java: a tool comparison

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Overview

Context and motivation

Introducing the tools

The qualitative comparison

Quantitively: sensitivity analysis

Quantitively: top 10 comparison

Wrapping up
1. Context and motivation
Plagiarism detection

- plagiarism and fraud are taken seriously at Utrecht University
- for papers we use Ephorus, but what about programs?
- plenty of cases of program plagiarism found
- includes students working together too closely
- reasons for plagiarism: lack of programming experience and lack of time
Manual inspection

- uneconomical
- infeasible:
  - large numbers of students every year
    - since this year 225, before that about 125
  - multiple graders
  - no new assignment every year: compare against older incarnations
- manual detection typically depends on the same grader seeing something idiosyncratic
Automatic inspection

- tools only list similar pairs (ranked)
- similarity may be defined differently for tools
- in most cases: structural similarity
- comparison is approximative:
  - false positives: detected, but not real
  - false negatives: real, but escaped detection
- the teacher still needs to go through them, to decide what is real and what is not.
  - the idiosyncracies come into play again
- computer and human are nicely complementary
Motivation

- various tools exist, including my own
- do they work “well”?
- what are their weak spots?
- are they complementary?
2. Introducing the tools
Criteria for tool selection

- available
- free
- suitable for Java
Guido Malpohl and others, 1996, University of Karlsruhe
web-service since 2005
tokenises programs and compares with Greedy String Tiling
getting an account may take some time
Jurriaan Hage, University of Utrecht, 2002
instrumental in finding quite many cases of plagiarism in Java programming courses
two Perl scripts (444 lines of code in all)
tokenises and uses Unix diff to perform comparison of token streams.
special facility to deal with reorderability of methods: “sort” methods before comparison (and not)
MOSS

- MOSS = Measure Of Software Similarity
- Alexander Aiken and others, Stanford, 1994
- fingerprints computed through winnowing technique
- works for all kinds of documents
  - choose different settings for different kinds of documents
Ahtiainen and others, 2002, Helsinki University of Technology

workings similar to JPLag

command-line Java application, not a web-app
Dick Grune and Matty Huntjens, 1989, VU.

software clone detector, that can also be used for plagiarism detection.

written in C
3. The qualitative comparison
The criteria

- supported languages - besides Java
- extendability - to other languages
- how are results presented?
- usability - ease of use
- templating - discounting shared code bases
- exclusion of small files - tend to be too similar accidentally
- historical comparisons - scalable
- submission based, file based or both
- local or web-based - may programs be sent to third-parties?
- open or closed source - open = adaptable, inspectable
Language support besides Java

- JPlag: C#, C, C++, Scheme, natural language text
- Marble: C#, and a bit of Perl, PHP and XSLT
- **MOSS**: just about any major language
  - shows genericity of approach
- Plaggie: only Java 1.5
- Sim: C, Pascal, Modula-2, Lisp, Miranda, natural language
Extendability

- JPlag: no
- Marble: adding support for C# took about 4 hours
- MOSS: yes (only by authors)
- Plaggie: no
- Sim: by providing specs of lexical structure
How are results presented

- **JPlag**: navigable HTML pages, clustered pairs, visual diffs
- **Marble**: terse line-by-line output, executable script
  - integration with submission system exists, but not in production
- **MOSS**: HTML with built-in diff
- **Plaggie**: navigable HTML
- **Sim**: flat text
Usability

- **JPlag**: easy to use Java Web Start client
- **Marble**: Perl script with command line interface
- **MOSS**: after registration, you obtain a submission script
- **Plaggie**: command line interface
- **Sim**: command line interface, fairly usable
Templating?

- JPlag: yes
- Marble: no
- MOSS: yes
- Plaggie: yes
- Sim: no
Exclusion of small files?

- JPlag: yes
- Marble: yes
- MOSS: yes
- Plaggie: no
- Sim: no
Historical comparisons?

- JPlag: no
- Marble: yes
- MOSS: yes
- Plaggie: no
- Sim: yes
Submission of file based?

- JPlag: per-submission
- Marble: per-file
- **MOSS**: per-submission and per-file
- Plaggie: presentation per-submission, comparison per-file
- Sim: per-file
Local or web-based?

- JPlag: web-based
- Marble: local
- MOSS: web-based
- Plaggie: local
- Sim: local
Open or closed source?

- JPlag: closed
- Marble: open
- MOSS: closed
- Plaggie: open
- Sim: open
4. Quantitively: sensitivity analysis
What is sensitivity analysis?

- take a single submission
- pretend you want to plagiarise and escape detection
- To which changes are the tools most sensitive?
- Given that original program scores 100 against itself, does the transformed program score lower?
- Absolute or even relative differences mean nothing here.
Experimental set-up

- we came up with 17 different refactorings
- applied these to a single submission (five Java classes)
- we consider only the two largest files (for which the tools generally scored the best)
  - Is that fair?
- we also combined a number of refactorings and considered how this affected the scores
- baseline: how many lines have changed according to plain diff (as a percentage of the total)?
The first refactorings

1. comments translated
2. moved 25% of the methods
3. moved 50% of the methods
4. moved 100% of the methods
5. moved 50% of class attributes
6. moved 100% of class attributes
7. refactored GUI code
8. changed imports
9. changed GUI text and colors
10. renamed all classes
11. renamed all variables
Eclipse refactorings

12. clean up function: use this qualifier for field and method access, use declaring class for static access

13. clean up function: use modifier final where possible, use blocks for if/while/for/do, use parentheses around conditions

14. generate `hashCode` and `equals` function

15. externalize strings

16. extract inner classes

17. generate getters and setters (for each attribute)
Results for a single refactoring

PoAs: MOSS (12), many (15), most (7), many (16)
reordering has little effect
Results for a single refactoring

- reordering has strong effect
- 12, 13 and 14 generally problematic (except for Plaggie)
Combined refactorings

- reorder all attributes and methods (4 and 6)
- apply all Eclipse refactorings (12 – 17)
Results for combined refactorings

\[\text{Sensitivity to combined modifications - QSortApplet}\]

![Bar chart showing similarity to version 0 (percent) for different tools: Diff, JPlag, Marble, MOSS, Plagie, SIM.]

- Diff: 30\%
- JPlag: 40\%
- Marble: 60\%
- MOSS: 10\%
- Plagie: 40\%
- SIM: 20\%
Results for combined refactorings

Sensitivity to combined modifications - QSortAlgorithm

Tool

Similarity to version 0 (percent)

0 20 40 60 80 100

Diff JPlag Marble MOSS Plagie SIM

Tool

Similarity to version 0 (percent)

0 20 40 60 80 100

Diff JPlag Marble MOSS Plagie SIM
General conclusions

- some tools score below simple diff!
- all tools do well for most, and badly for a few refactorings.
- differences depend on the program: sometimes certain refactorings have no effect
- except Marble all tools have a hard time with reordering of methods
- Eclipse clean-up refactorings can influence scores strongly (which is bad!)
- MOSS bad on variable renaming
- combined refactorings are much harder to deal with
  - and we could have made it worse.
5. Quantitively: top 10 comparison
Rationale

▶ an extremely insensitive tool can be very bad: every comparison scores 100.
▶ normally, tools are rated by precision and recall:
  ▶ when we kill 75 percent of the bad guys, how much collateral damage is there?
▶ depends on knowing who is bad and who is good
▶ too much manual labour for us, so we approximate
Top 10 comparison

➤ consider top 10 file comparisons of each tool
➤ consider each of them manually to decide on similarity
➤ for bad guys in the top 10 in tool X, we hope to find these in the top 10 of all tools
➤ for good guys in the top 10 of X, we hope not to find it in any other top 10
Mandelbrot assignment: small, typically one class, from course year 2002 up to course year 2007

913 submissions in all, with a number of known plagiarism cases in there

the top-10 of the five tools generate a total of 28 different pairs (min. 10, max. 50)
Manual comparison

- 3 self comparisons
- 5 resubmissions
- 11 false alarms
- 5 plagiarism
- 3 similar (but no plagiarism)
- 1 due to smallness
Some highlights

- Plaggie has many false alarms, and many real cases do not attain the top 10
- Plaggie and JPlag “failed” on uncompilable sources
- JPlag misses a plagiarism case that the others did find
- easy misses by MOSS (similar) and Sim (resubmission)
- Marble does generally well, assigning substantial scores to all plagiarism and similar cases
6. Wrapping up
Conclusions

- comparison of five plagiarism detection tools (for Java)
- qualitatively on an extensive list of criteria
- quantitively by means of
  - sensitivity to plagiarism masking
  - top-10 comparison between tools
- in terms of maturity of tool experience, JPlag ranks highest
- genericity leads to unspecificity (MOSS)
- except for Marbe, tools can’t deal with reordering of methods
- tool need to improve to deal well with combined refactorings
Future work

- other tools: Sherlock, CodeMatch (commercial), Sid (?)
- other languages?
- making the experiment repeatable
- larger collections of programs
- other quantitative comparison criteria