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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 assigment 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

JPlag

- 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

Marble

- 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

Plaggie

- Ahtiainen and others, 2002, Helsinki University of Technology
- workings similar to JPLag
- command-line Java application, not a web-app

Sim

- 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)?

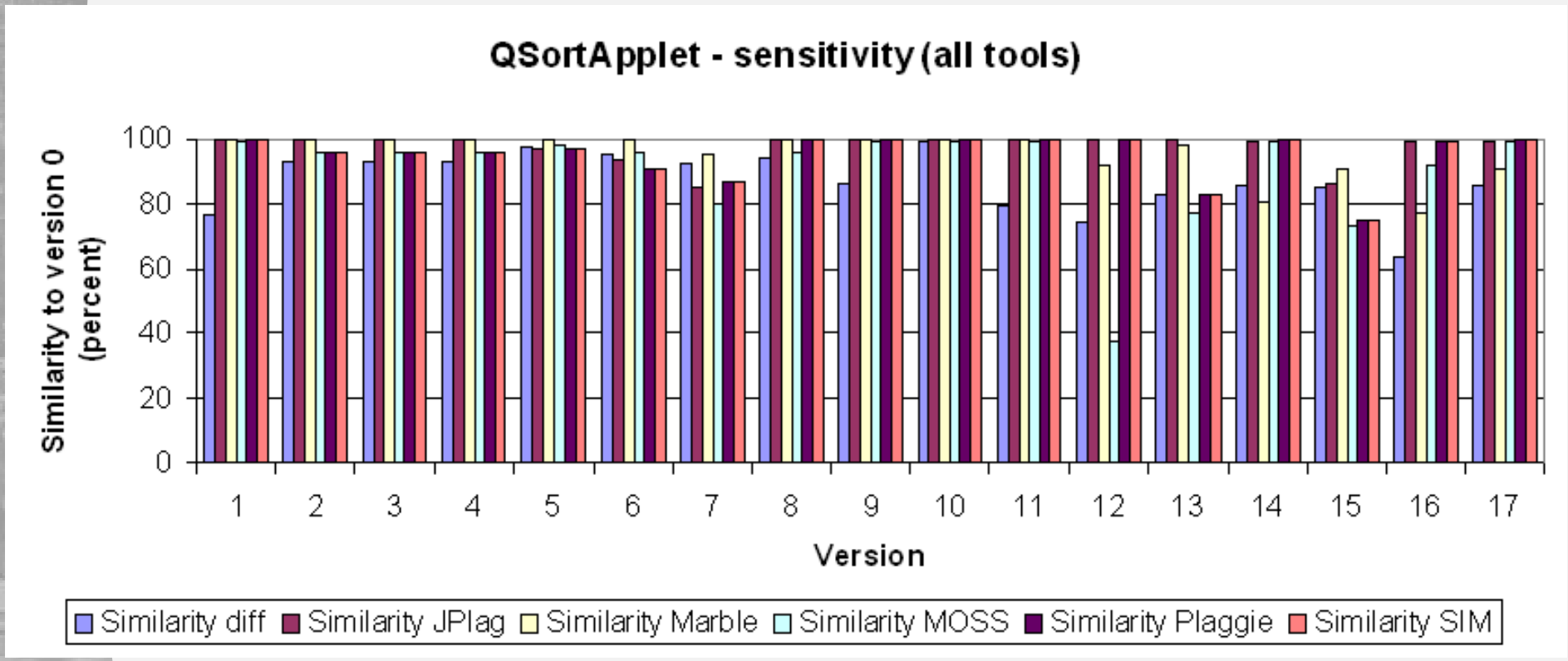
The first refactorings

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

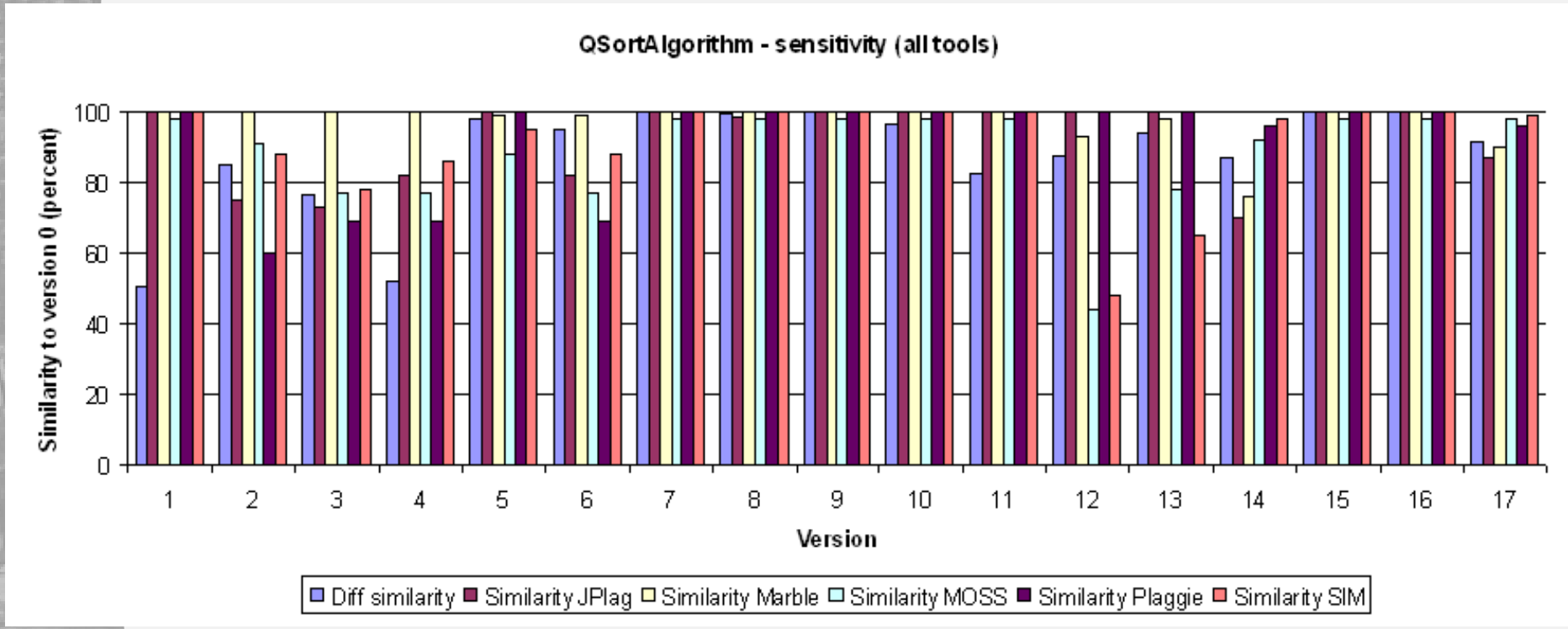
12. clean up function: use this qualifier for field and method access, use declaring class for static access
13. clean up function: use modifier final where possible, use blocks for if/while/for/do, use parentheses around conditions
14. generate `hashcode` and `equals` function
15. externalize strings
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

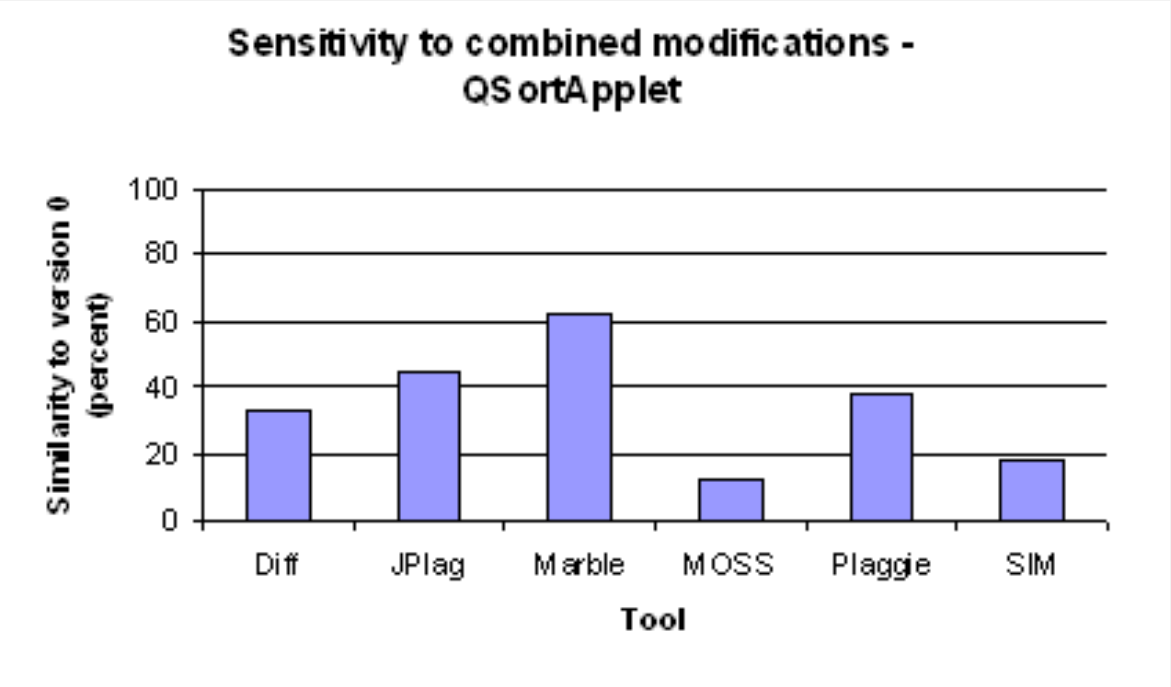


- reordering has strong effect
- 12, 13 and 14 generally problematic (except for Plaggie)

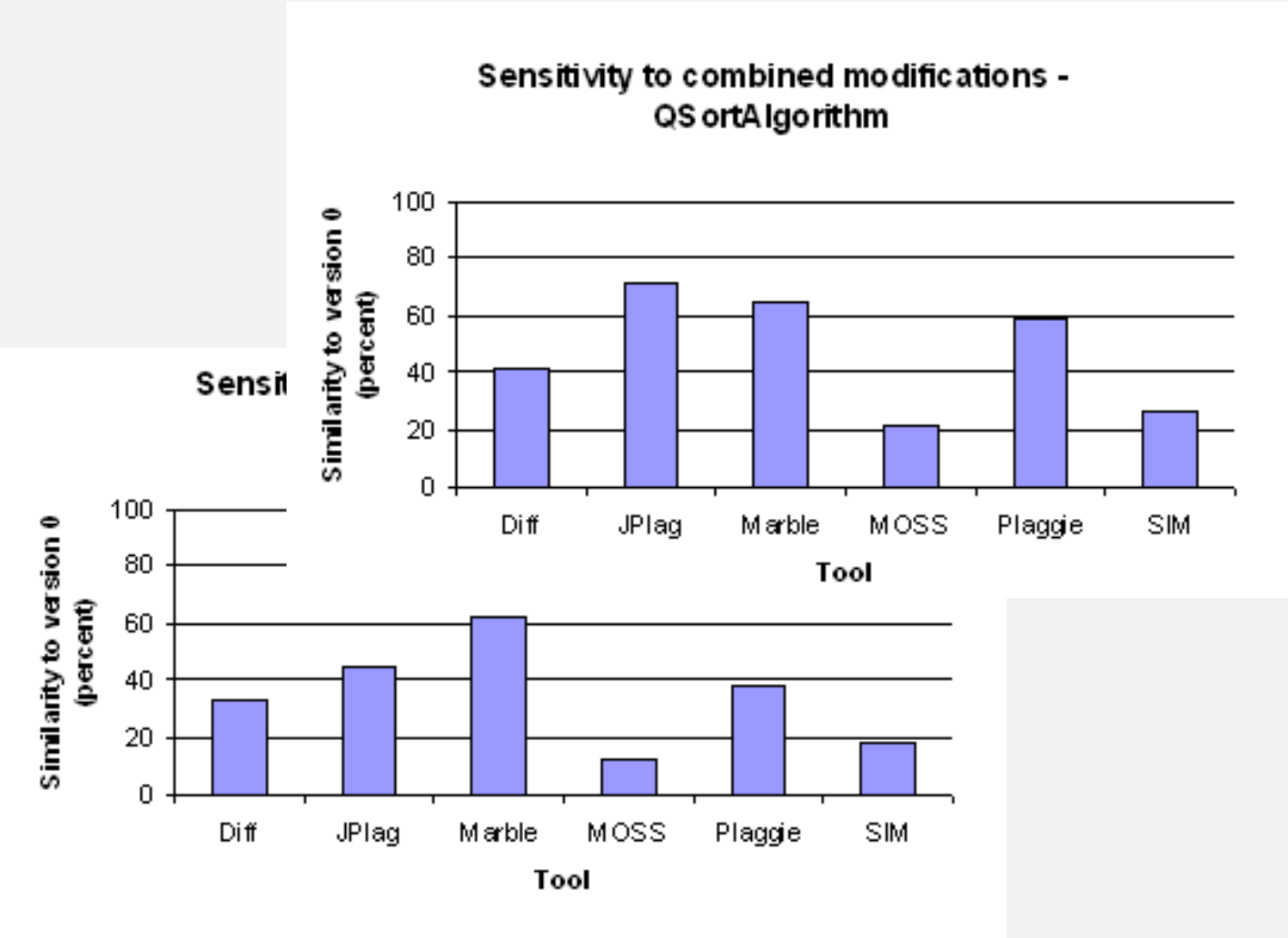
Combined refactorings

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

Results for combined refactorings



Results for combined refactorings



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

Data

- 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 plagariasm 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