Comparative Study of Code Query Technologies

Tiago Alves
Software Improvement Group

**Company**
- Spin-off from CWI in 2000, self-owned, independent
- Management consultancy grounded in source code analysis
- Innovative, strong academic background, award-winning, profitable

**Services**
- Software Risk Assessments (snapshot) and Software Monitoring (continuous)
- Toolset enables to analyze source code in an automated manner
- Experienced staff transforms analysis data into recommendations
- We analyze over 50 systems annually
- Focus on technical quality, primarily maintainability / evolvability
Services

**DocGen**
- Automated generation of technical documentation

**Assessments**
- In-depth investigation of software quality and risks

**Monitoring**
- Continuous measurement and decision support

**Certification**
- Five levels of technical quality
Who is using our services?
Background

- **Extract**
  - Facts and relations and represent them an intermediary structure

- **Abstract/Enrich**
  - Add new facts and relations

- **Present**
  - Visualize or extract information
Motivation

• **Current implementation of SIG tooling**
  - Extract: graph to store facts for several languages
  - Abstract/enrich: implemented using Java visitors
  - Present: through tables and charts

• **Problems**
  - Implementation verbose and imperative
  - Reuse among analyses difficult
  - Error prone

• **Use of code query technologies to improve SIG developer’s productivity**
  - Replace current imperative implementation by a more declarative one
Code Query Technologies - Timeline

- Grok, JGrok
  - Ric Holt, Canada
  - Implemented in Turing

- Rscript
  - Paul Klint, Netherlands
  - Implemented in ASF+SDF

- JRelCal
  - Tijs van der Storm, Netherlands
  - Implemented in Java

- GraLab, JGraLab
  - Jürgen Ebert, Germany
  - Implemented in Java

- SemmleCode
  - Oege de Moor, UK
  - Implemented in Java

- CrocoPat
  - Dirk Beyer, Germany
  - Implemented in C

- JTransformer
  - Günter Kniesel, Germany
  - Implemented in Java

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Comparison

- **Code query example**
  - Experience the language and tool

- **Language criteria**
  - Overview of the language features

- **Tool criteria**
  - Overview of the tool features
Language criteria

- **Style/Paradigm**
  - Compare implementation conciseness

- **Types**
  - Support for Integers, Chars, Strings, ...

- **Parametrization**
  - Behavior depends on a parameter value

- **Polymorphism**
  - Abstract over the entities types

- **Modularity**
  - Reuse of queries to construct other queries

- **Libraries**
  - Support for libraries of queries
Tool criteria

- **Output formats**
  - Text, preformatted text, tables, charts, others?

- **Interactive interface**
  - Command line interface (CLI), Graphical user interface (GUI), Eclipse plug-in

- **API support**
  - Invocations of the functionality from a host program

- **Interchange format**
  - To store facts from the extraction and results of abstraction

- **Extraction support**
  - None, Java, C/C++, XML, others?

- **Licensing**
  - Free, Open-source, Proprietary
Scenarios

- **Interactive use**
  - The tool is used directly by the software analyst (exploratory)
  - The user specifies and executes the queries, and extracts results

- **Tool integration**
  - The tool is used by a programmer as a component to build other tools
  - Reimplementation of existing functionality
## Criteria vs. Scenarios

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Afferent Coupling

Ca = # of classes outside the package that depend upon classes within the package
Ca = \{(P1, C5), (P1, C7), (P2, C2)\}

Efferent Coupling

Ce = # of classes inside the package that depend upon classes outside the package
Ce = \{(P1, C2), (P2, C5), (P2, C7)\}

Package Instability \( I = \frac{Ce}{Ca + Ce} \)

\[ I = \{(P1, 1 / (2 + 1)), (P2, 2 / (1 + 2))\} = \{(P1, 0.33), (P2, 0.67)\} \]
Input Relations

Relations

PackageOf : Package x Class

ClassOf : Class x Method

MethodCall : Method x Method
Implementation guidelines

Defined relations

ClassDepInterPackg : Class x Class

AffCoupling : Package x Class
EffCoupling : Package x Class

AfferentCoupling : Package x N
EfferentCoupling : Package x N

PackageInstability : Package x N
Lifting implementation example

Input relations

- `PackageName : Package x Class`
- `ClassOf : Class x Method`
- `MethodCall : Method x Method`

Compute lifting

- `ClassDep : Class x Class`
  - `= ClassOf o MethodCall o inv (ClassOf)`
- `PackageDep : Package x Package`
  - `= PackageOf o ClassDep o inv (PackageOf)`
PackageDep := PackageOf o ClassDep o (inv PackageOf)

PackgDepInterPackg := PackageDep - (id dom PackageOf)

ClassFowardRel := (inv PackageOf) o PackgDepInterPackg o PackageOf

ClassDepInterPackg := ClassForwardRel ^ ClassDep

AffCoupling := PackageOf o (inv ClassDepInterPackg)

AfferentCoupling := (dom AffCoupling) outdegree (AffCoupling)
rel[str,str] PackageOf
rel[str,str] ClassOf
rel[str,str] MethodCall

rel[&T1, int] outdegree(rel[&T1,&T2] R)
    = { <D, #R[D]> | <&T1 D, &T2 U> : R }

rel[str,str] ClassDepInterPackg
    = { <C1,C2> | <str C1, str C2> : ClassDep
        , PackageOf[-,C1] != PackageOf[-,C2] }

rel[str,str] AffCoupling = PackageOf o inv(ClassDepInterPackg)

rel[str,int] AfferentCoupling = outdegree(AffCoupling)

rel [str,int] PackageInstability
    = { <P1, (100*N1)/(N1+N2)> | <str P1, int N1> : EfferentCoupling
        , <str P2, int N2> : AfferentCoupling, P1 == P2 }
Relation<String, String> packageDep
    = packageOf.compose(classDep.compose(packageOf.inverse()));

Relation<String, String> packgDepInterPackg
    = packageDep.difference(packageOf.domain().id());

Relation<String,String> classForwardRel
    = (packageOf.inverse()).compose(packgDepInterPackg).compose(packageOf);

Relation<String,String> classDepInterPackg
    = classForwardRel.intersection(classDep);

Relation<String,String> affCoupling
    = packageOf.compose(classDepInterPackg.inverse());

Relation<String,Int> afferentCoupling = affCoupling.outdegree();
predicate classDepInterPackg(Class c1, Class c2) {
    c1.getPackage() != c2.getPackage() and classDep(c1, c2)
}
class MyPackage extends Package {
    MyPackage() {
        this.fromSource()
    }

    predicate affCoupling(Class c) {
        exists(Class c1 | this.contains(c1) and classDepInterPackg(c1, c))
    }

    int afferentCoupling() {
        result = count(Class c | this.affCoupling(c))
    }

    float packageInstability() {
        result = (1.0 * this.efferentCoupling()) / 
                  (this.afferentCoupling() + this.afferentCoupling())
    }
}
from p : V {JavaPackage}
reportMap p,
  from outerClass : V {JavaClass}
  with
    (not p --> {PackageOf} outerClass) and
    (p --> {PackageOf} <-- {ClassDep} outerClass)
  report outerClass end
end store as AffCoupling

using AffCoupling:
from p : V {JavaPackage}
reportMap p, count(get(AffCoupling,p)) end
store as AfferentCoupling

using AfferentCoupling, EfferentCoupling:
from p : V {JavaPackage}
reportMap p, get(EfferentCoupling,p) /
  ( get(EfferentCoupling,p) + get(AfferentCoupling,p))
end store as PackageInstability
ClassDepInterPackg(c1,c2)
  := EX( p1, PackageOf(p1, c1) & EX( p2, PackageOf(p2, c2) &
                                            !=(p1,p2) & ClassDep( c1, c2)));

AffCoupling(p,c)
  := EX( c1, PackageOf( p, c1) & ClassDepInterPackg( c, c1));

Package(x) := PackageOf(x,_) ;

FOR p IN Package(x) {
  ca := #(AffCoupling(p,c));
  PRINT "AfferentCoupling ", p, " ", ca, ENDL;

  ce := #(EffCoupling(p,c));
  PRINT "EfferentCoupling ", p, " ", ce, ENDL;

  i := ce / (ca + ce);
  PRINT "Instability ", p, " ", i, ENDL;
}
classDepInterPackg(C1, C2) :-
    packageOf(P1, C1), packageOf(P2, C2),
    not(P1 = P2), classDep(C1, C2).

affCoupling(P, C) :-
    packageOf(P, C1), classDepInterPackg(C, C1).

afferentCoupling(P, N) :-
    setof(C, affCoupling(P, C), AffClasses),
    length(AffClasses, N).

packageInstability(P, I) :-
    efferentCoupling(P, Ec),
    afferentCoupling(P, Ac),
    I is Ec/(Ec + Ac).
## Language comparison

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<th>Grok</th>
<th>Rscript</th>
<th>JRelCal</th>
<th>SemmleCode</th>
<th>CrocoPat</th>
<th>JGraLab</th>
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## Tool comparison

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Summary

- **Language criteria**
  - No significant differences found
  - It is not possible to implement Package Instability in Grok

- **Tool criteria**
  - Significant differences: interchange format, extraction, licensing
  - Poor support for extraction

- **Interactive use**
  - Only JRelCal is less suitable.

- **Tool integration**
  - JRelCal, SemmleCode, CrocoPat, JGraLab, JTransformer
  - Grok, Rscript only through interchange format
Conclusion

- **Compared seven code query technologies**
  - Package instability example
  - Six language criteria
  - Six tool criteria

- **Comparison not evaluation**

- **Presented findings**
  - Allow an informed decision about which tool to choose
Future work & challenges

• **Future wok**
  * Add more tools / formalisms
  * Performance comparison

• **Challenges**
  * Adoption of each tool stronger points
  * Better support for libraries, interchange format and extractors
  * Availability of API
  * Interfacing through IDE

• **Research directions**
  * Analyze several versions of software
  * Architecture checking
Questions?

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